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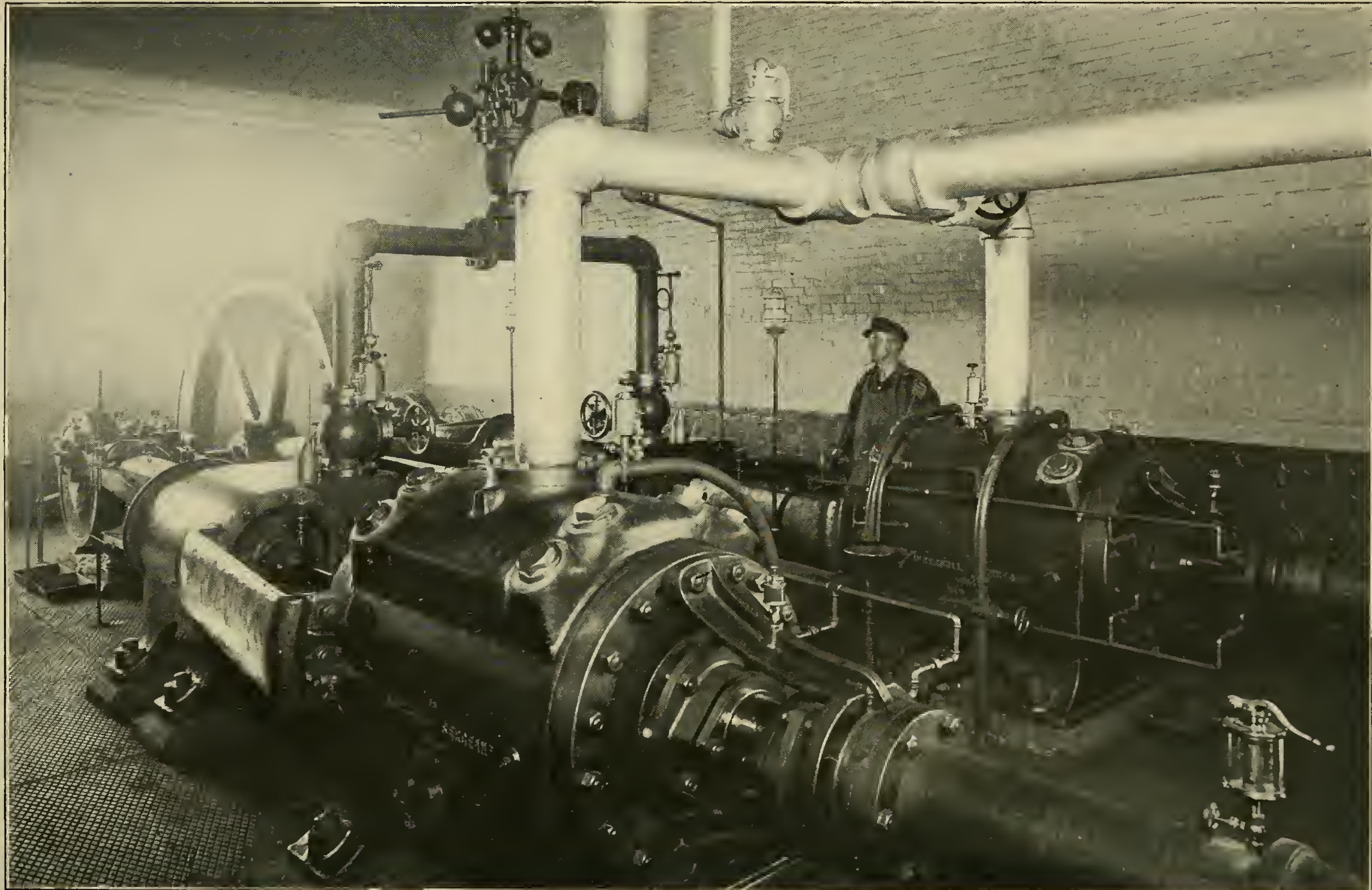
ABBREVIATIONS. — D. = Discussion; I. = Illustrated.
Names of authors are printed in *italics*.



INGERSOLL-SERGEANT GAS COMPRESSOR.

ASSOCIATION OF ENGINEERING SOCIETIES.

Organized 1881.

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TEST OF GAS COMPRESSOR NO. 3 OF THE NEW ORLEANS GAS LIGHT COMPANY, SATURDAY, JANUARY 9, 1909.

BY W. B. GREGORY, MEMBER LOUISIANA ENGINEERING SOCIETY.

[Read before the Society, March 8, 1909.]

1. *Object of test.*

The object of this test was to determine the mechanical efficiency of the cross-compound single-stage compressor, built by the Ingersoll-Sergeant Drill Company; to determine the values of "n" for the compression curve; and to determine approximately the amount of steam per indicated horse-power hour.

2. *Formulæ.*

The steam indicated horse-power was calculated from the steam indicator cards by the following formula:

$$\frac{P_s l a_s n}{33\ 000} = \text{i.h.p.} \qquad 1.$$

The indicated horse-power for the gas compression was calculated in the same way from the gas compression cards.

$$\frac{P_g l a_g n}{33\ 000} = \text{Gas i.h.p.} \qquad 2.$$

The cards were taken simultaneously and the ratio of (2) divided by (1) was determined.

3. *Method of performing the test.*

The method of performing the test was to take indicator cards simultaneously from the high pressure and low pressure steam cylinders and the right and left gas compressor cylinders.

TEST OF GAS

Number	Time	Temperatures Gas Entering	Temperatures Gas Leaving	Temperatures Water Entering	Temperatures Water Leaving	Room	Steam Pressure	Recording Gauge	Intake Press Inches Water	Discharge Gas Pressure Gauge	Rev. Counter	R.P.M. for 20 min	R.P.M. for Card
1	12:00	75.4	210	82.	83	71	108	118	-1.8		125244		53
2	:20	76.4	218	82	84	77	109	118	-1.8		6405	58	71
3	:40	76.4	211.5	82	88	77.2	113	122	-2.15		7523	55.8	55
4	1:00	77.4	208.5	82	89	79.	113	122	-1.7		8563	52	55
5	:20	77.4	218.5	82	91	79	115	123	-1.8		9713	57.5	57
6	:40	77.9	214	82	90.5	80	105	113	-2.3		130782	53.45	51
7	2:00	77.9	225	82	94.5	79	110	118	-2.3		1851	53.4	52
8	:20	78.9	230	82.1	93.5	81	111.5	120	-2.05		2869	50.9	54
9	40	78.9	218	82.6	88	80.5	104	112	-2.07		3904	51.7	50
10	3:00	78.9	212.4	82.2	88	80.5	101	109	-1.9		4960	52.8	49
11	:20	79.4	208	82.6	88	80.5	100.	108	-2.5		5993	51.6	50
12	:40	80.4	218	81.6	88	80.	101	110	-1.5		7192	59.9	58
13	4:00	79.9	232	80	89	79	106	114	-2.1		8326	56.7	52
14	:20	79.4	223	80.8	89.8	80	97.	105	-3.3		9251	46.2	44
15	:40	79.4	220	80	89.3	79.	102	110	-2.8		140277	51.3	49
16	5:00	79.4	227.8	81	89	79	113	121	-1.0		1550	63.6	68
17	:20	78.4	230	82	90	79	110	118	-1.0		2797	62.3	64
18	:30			82	91.5	79					3649		92
19	:40	77.4	258	82	93.	79	118	126	-2.8		4541	87.2	75
20	6:00	76.9	249	83	89	79	109	120	-2.35	38.5	6285	87.2	80
21	:20	76.4	252	82	92	77	109	121	-2.9	38.7	8017	86.6	90
22	:40	76.4	248	83	91.8	76	110.5	120	-3.4	37.8	9808	89.5	88
23	7:00	76.4	240	81	90.8	76	109.	118	-2.3	34.8	151493	84.2	87
24	:20	76.4	240	81	90.	75	108	118	-3.3	34.8	3175	84.1	86
25	:40	74.4	228	81	90	74	105	117	-0.35	33.9	4820	82.2	74
26	8:00	74.9	214	81	88	75	105	115	- 4	30.3	6271	72.5	78
27	:20	74.4	222	80	87	75	105	117	+1.8	31.9	7647	68.8	68
28	:40	75.4	220	81	87	74	107	115	+1.8	31.3	8827	59.0	59
29	9:00	74.9	220	80	86	73	104	113	+1.3	31.1	9926	54.9	55
30	:20	75.4	218	80	87.5	74	110	119	+2.9	31.4	161048	56.1	54
31	:40	75.4	219	79	86.5	73	103	112	+2.2	29.9	2089	52.1	57
32	10:00	75.4	212	79	86	73	108	116	+3.6	30.1	3124	51.8	46
33	:20	74.4	210	79	86	73	96	108	+3.3	28.9	4080	47.8	32
34	:40	74.4	210	80	87	73	107	115	+4.1	31.2	5087	50.4	44
35	11:00	74.4	206	80	86.5	73	104	115	+2.7	30.5	5949	43.1	41
36	:20	73.9	190	80	85.5	72	116	125	+2.7	25.8	6668	35.9	57
37	:40	73.4	170	79	84	71	105	117	+3.8	20.8	7363	34.8	34
38	12:00	73.9	150	76	82.	72	117	120	+2.8	14.3	7990	31.1	35

Compressor, January 9, 1909.

INDICATED HORSE POWER														
Steam					Gas									
H.P.		L.P.		Total	Right		Left		Total	Ratio Gas I.H.P. / Steam I.H.P.	B.T.U.'s per min. to Jacket Water (Average)	H.P. Equivalent to Jacket Cooling	Gas I.H.P. + J.H.P.	Ratio (Gas I.H.P.+J.H.P.) / Steam I.H.P.
Crank	Head	Crank	Head		Head	Crank	Head	Crank						
28.7	30.4	52.9	49.8	161.8	30.0	34.3	31.4	31.1	126.8	.784	231	5.42	132.2	.817
51.1	48.7	66.5	69.6	235.9	59.0	67.3	46.4	47.8	220.5	.935	460	10.90	231.4	.981
30.9	31.4	51.9	52.2	166.4	34.2	36.3	33.4	32.3	135.2	.813	1183	27.9	164.1	.987
29.6	29.1	51.9	50.7	161.3	33.5	35.0	31.2	33.7	133.4	.826	1281	30.2	163.6	1.013
37.1	35.2	55.8	54.3	182.4	37.2	39.8	35.6	36.1	148.7	.815	1630	38.4	187.1	1.025
28.8	27.2	49.0	48.1	153.1	32.4	34.4	31.0	29.2	127.0	.829	1050	24.8	151.8	.992
29.8	29.8	52.7	52.0	164.3	33.5	36.1	31.6	32.4	133.6	.812	925	21.8	155.4	.945
30.3	31.3	53.6	52.9	168.1	34.6	36.6	33.9	32.9	138.0	.820	1150	27.2	165.2	.983
28.2	27.7	43.2	41.9	141.0	33.0	32.2	30.1	28.7	124.0	.880	1040	24.6	148.6	1.053
25.6	24.2	49.9	45.9	145.6	28.6	28.8	28.2	28.8	114.4	.786	1130	26.7	141.1	.970
26.5	26.1	46.7	40.8	140.1	28.2	30.0	27.8	27.7	113.7	.810	1200	28.3	142.0	1.013
35.8	35.8	59.0	54.3	184.9	34.4	35.6	35.1	36.1	141.2	.765	1340	31.7	172.9	.935
35.3	33.6	57.1	52.9	178.9	36.9	39.0	35.6	37.1	148.6	.830	1640	38.6	187.2	1.046
21.9	22.4	41.0	41.0	126.3	29.9	29.2	30.1	22.3	111.5	.883	1650	39.0	150.5	1.190
25.1	25.8	44.9	44.9	140.7	31.9	32.0	29.0	24.7	117.6	.837	1720	40.6	158.2	1.125
45.8	44.0	67.7	65.2	222.7	46.4	46.1	45.6	43.7	181.8	.818	1460	34.5	216.3	.973
34.9	37.9	57.9	55.1	185.8	36.9	38.2	37.5	37.3	149.9	.807	1460	34.4	184.3	.993
77.6	78.3	94.3	88.7	338.9	70.0	67.6	66.2	68.5	272.3	.804	1750	41.4	313.7	.925
61.8	63.0	74.2	73.3	272.3	50.1	55.1	56.0	57.8	219.0	.805	2050	48.3	267.3	.982
64.8	65.2	75.2	71.3	276.5	54.5	60.0	57.6	60.0	232.1	.840	1110	26.2	258.3	.935
75.9	75.0	89.0	84.5	324.4	63.3	67.5	67.0	71.0	268.8	.829	1840	43.4	312.2	.963
95.0	96.4	67.5	61.2	320.1	63.5	69.0	65.6	68.0	266.1	.832	1610	38.0	304.1	.950
94.5	97.4	53.6	51.6	297.1	56.8	59.6	59.9	65.2	241.5	.814	1790	42.3	283.8	.955
94.5	96.2	55.5	54.1	300.3	59.2	63.3	61.9	64.4	248.8	.829	1640	38.8	287.6	.958
80.4	82.8	43.2	39.6	245.7	47.6	50.6	49.6	50.1	197.9	.806	1640	38.8	236.7	.965
82.0	82.7	40.1	37.3	242.1	47.2	50.3	48.5	50.7	196.7	.816	1290	30.4	227.1	.938
75.5	70.5	31.8	36.0	213.8	42.7	45.9	44.2	46.5	179.3	.839	1290	30.4	209.7	.980
62.6	61.3	28.0	28.2	180.1	36.8	39.4	37.7	38.9	152.8	.847	1090	25.6	178.4	.991
58.6	57.9	26.1	25.5	168.1	33.2	35.1	33.6	35.5	137.4	.817	1120	26.4	163.8	.975
56.0	54.7	26.9	25.3	162.9	33.2	35.2	33.7	34.4	136.5	.838	1370	32.2	168.7	1.033
59.0	58.3	26.3	25.8	169.4	36.7	35.2	36.8	35.4	144.1	.851	1360	32.0	176.1	1.038
44.4	43.2	20.9	20.7	129.2	27.0	29.2	26.1	25.8	108.1	.837	1270	30.0	138.1	1.069
30.9	28.5	14.3	14.4	88.1	18.2	19.4	17.4	17.3	72.3	.821	1370	32.4	104.7	1.187
43.8	41.8	19.2	19.1	123.9	26.6	29.0	24.9	24.6	105.1	.849	1380	32.6	137.7	1.011
41.5	39.3	17.7	19.2	117.7	24.0	24.5	24.3	23.7	97.5	.830	1310	30.9	128.4	1.092
44.9	41.0	28.9	28.3	143.1	31.0	28.6	28.0	26.3	113.9	.796	1080	26.4	140.3	.982
17.8	17.8	12.5	11.5	59.6	0.64	13.3	14.3	12.4	40.6	.681	1040	24.6	65.2	1.093
18.0	18.3	12.9	12.4	61.6	10.8	10.9	11.3	11.1	45.1	.730	1230	29.0	74.1	1.202
							Mean			.820				1.007

Observations were also taken of the revolutions per minute, the temperatures of entering and leaving gas, and of entering and leaving jacket water used for cooling the compressed gas and the gas cylinder stuffing boxes, the time of flow for 200 lbs. of this water, the boiler pressure, and the gas intake and discharge pressures. A revolution counter was read every twenty minutes, and a one-minute observation was taken at the time of obtaining each set of indicator cards. The horse-powers from the cards were obtained by using the one-minute observations of revolutions per minute. Time of water flow and its temperature were read continuously at intervals of about one and one-quarter minutes. Indicator cards, temperatures and all other observations were taken every twenty minutes.

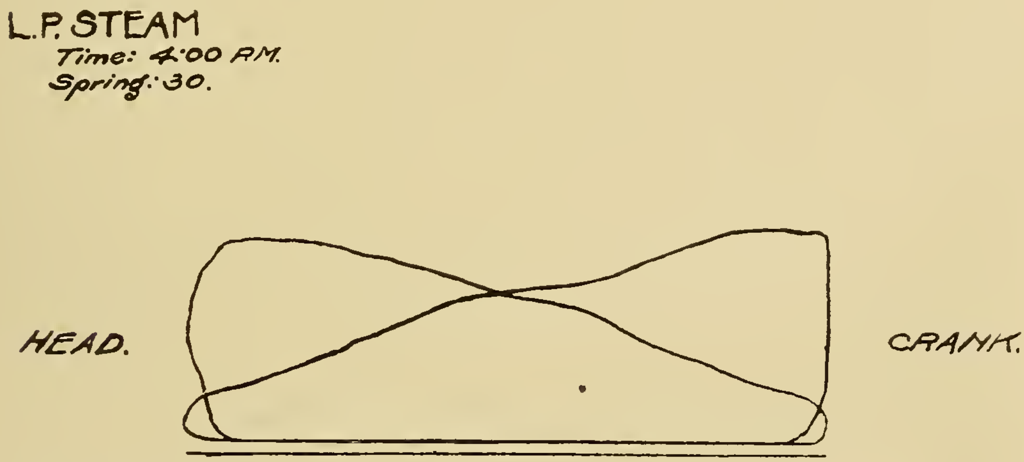
4. *Description of the compressor.*

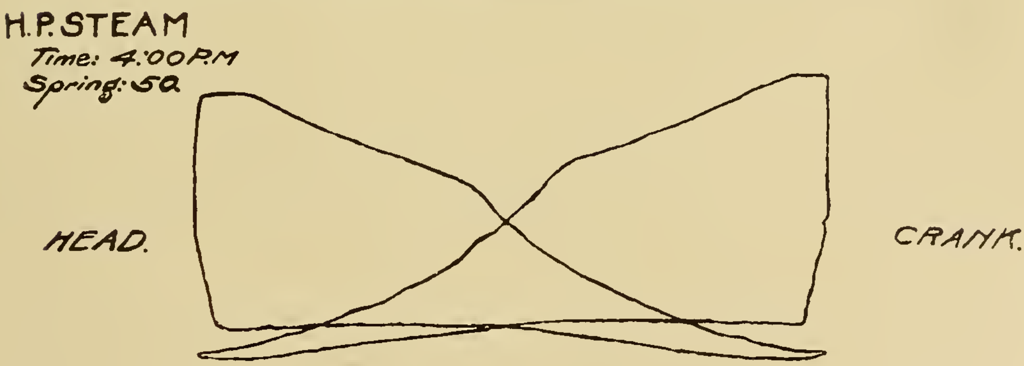
The compressor consists of a horizontal cross-compound steam engine with Meyer slide valves, the cylinders being arranged on opposite sides of a very heavy fly wheel, and a single-stage gas compressor cylinder being built tandem to each steam cylinder on the head end of the steam cylinder. The gas compressor cylinder tandem to the low pressure steam cylinder is called the right gas cylinder, and the other, the left gas cylinder. The high pressure and low pressure steam cylinders are 23 in. and 34 in. respectively in diameter, and the gas compression cylinders are $28\frac{1}{4}$ in. in diameter. The common stroke is 2 ft. The clearance of the left gas cylinder is $\frac{3}{16}$ in. on each end, and in the right gas cylinder it is $\frac{3}{16}$ in. on the head end and $\frac{3}{32}$ in. on the crank end. The head and crank end piston rods of both steam cylinders are $3\frac{3}{16}$ in. in diameter, the crank end piston rods of the gas cylinders are $3\frac{3}{8}$ in. in diameter, and the head and hollow piston rods are $7\frac{1}{4}$ in. in diameter. The gas is admitted through these hollow piston rods, which work through a stuffing box, into the gas pipe entering the hollow piston, and then through suction valves into the cylinder. The delivery is through six automatic valves attached to the periphery at each end of the cylinders. As three-way cocks were used, only one indicator was required for each cylinder. The indicator motions were taken from the cross-heads through wheel-reducing motions. The water for cooling the gas cylinders and stuffing boxes was led through pipes to two barrels on separate scales, and the water delivery pipes were shifted alternately from one to the other. The time for 200 lb. of water to flow was taken with a stop-watch. Not all the water was weighed, but the rate of flow was found at intervals of little more than a minute.

The compressor is used to force gas into the mains to supply outlying districts in the city of New Orleans. The pressure is varied by varying the speed of the engine to suit the demands for gas. This is done by throttling the steam for the high pressure cylinder. The gas compressed is received from large holders 200 or 300 ft. from the compressor. The pressure at the suction intake is approximately atmospheric; the variation is shown in the log. The test lasted from twelve noon to twelve midnight, and the pressures were varied between 10 and 40 lb. per square inch.

5. *Discussion of the indicator cards.*

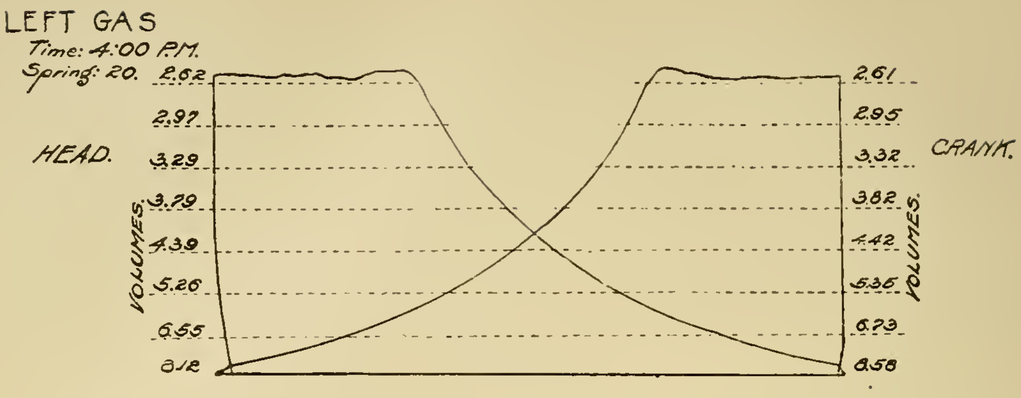
The indicator cards from the steam cylinders show the work given up by the steam to the engine. This work is used in several ways:





1. Gas compression.
2. Heating of gas during compression.
3. Heating jacket water.
4. Friction of machine.

1 and 2 are found from the indicator cards of the gas cylinders.



Compression of a gas, or a mixture of gases, accomplished very slowly, so that the compression is effected without change of temperature, is known as isothermal compression. The curve of compression in that case is an equilateral hyperbola, asymptotic to the lines of zero pressure and zero volume. The equation of the curve is $PV^1 = C$. P and V represent absolute pressure and volume, respectively.

Compression accomplished so rapidly that no heat is extracted from the gas is known as adiabatic compression. The equation of the curve of compression in that case is $PV^n = C$, in which P and V are absolute pressure and volume, respectively, at any point on the curve. and "n" is the ratio of specific heat at constant pressure to that at constant volume for the gas or mixture of gases.

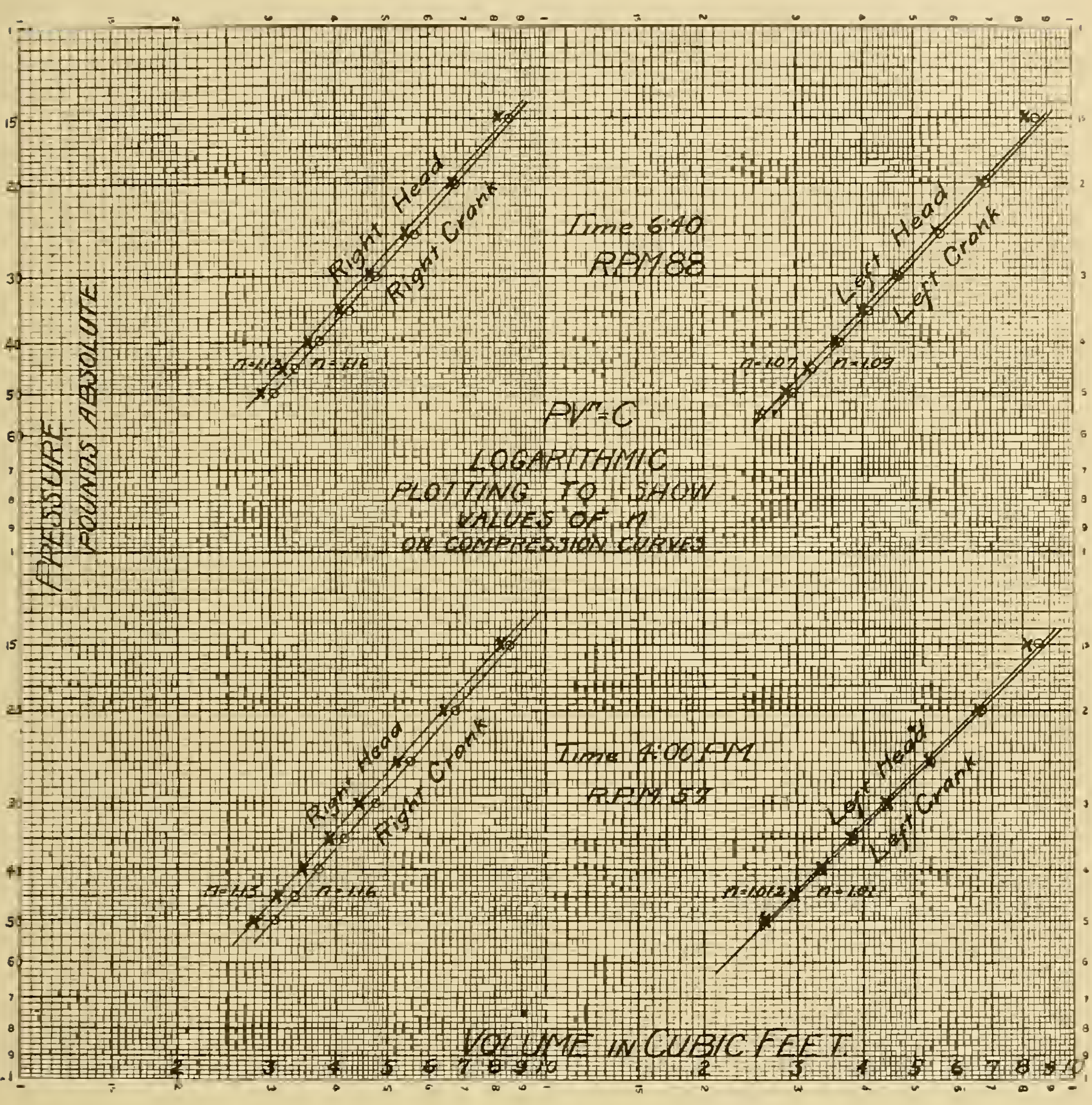
If the analysis of the gas is known, the value of "n" may be computed. The average analysis was given, and the computation below made for theoretical "n."

I. Constituents.	II. Per Cent. Weight.	III. Weight of One Cu. Ft. in Lb.	IV. Weight in One Cu. Ft. of the Mixture. Lb.	V. Ratio $\frac{K_p}{K_v}$	VI. IV × V.
CO_2	2.40	.12267	.00295	1.29	.00381
C_2H_4	9.00	.07809	.00703	1.26	.00886
O	0.50	.08921	.00045	1.41	.000635
CO	31.00	.07807	.0242	1.41	.0341
H	35.20	.00559	.00197	1.41	.00278
CH_4	18.50	.04464	.00827	1.32	.01090
N	3.40	.07831	.00266	1.41	.00375
			.04753		.06484

$$n = \frac{.06484}{.04753} = 1.364$$

In any practical case a part of the heat of compression is given up to the jacket water, and the actual curve of compression lies between the isothermal and adiabatic curves.

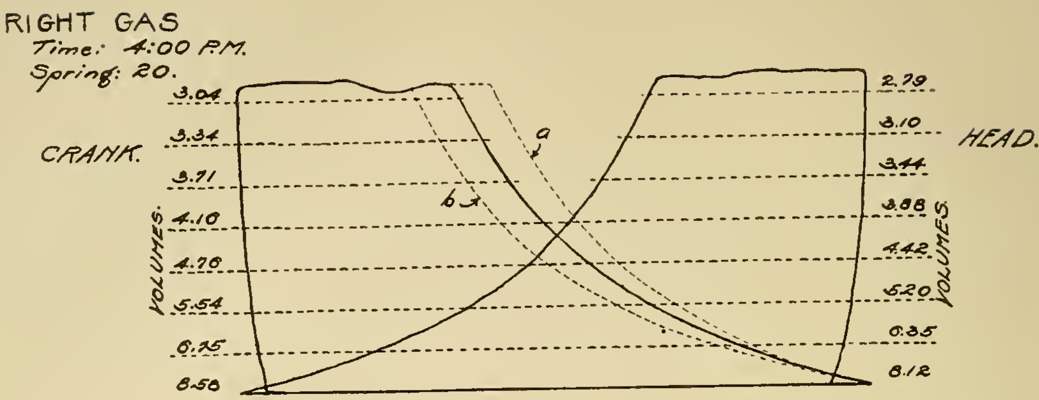
Some of the gas cylinder indicator cards were worked up on logarithmic plotting paper, and the actual value of "n" in the



equation $PV^n = C$ was found from these plots. The average values found for "n" were:

R. P. M.	Left Compressor.	Right Compressor.
88	1.080	1.140
57	1.011	1.145

The smaller value of "n" in the left gas compressor as well as the variance of its values at the differing revolutions per minute was due to a leak past the piston in that cylinder. The cylinder had been scored by a broken valve.



On the indicator cards from which the actual "*n*" was found, the curve of adiabatic compression, $PV^{1.364} = C$, was plotted. This is curve "*a*." The curve of isothermal compression, $PV^1 = C$, was also plotted. This is curve "*b*." The area included between the isothermal curve and the actual curve represents the work given up to the gas as heat. This was found to be 10 per cent. of the area of the actual card. The area included between the actual curve and the adiabatic represents the work given up to the jacket as heat, and the friction of rings and rod of compressor cylinder. This amounts to 8.13 per cent. of the area of the actual card.

6. *Water observations.*

Water was circulated around the stuffing boxes of the gas cylinders, and this water was weighed with the jacket water, and the temperature of the mixture was observed. In this way the heat given to the jacket, which was calculated from the water observations, included also a part of the frictional losses in the machine. Thus the sum of the gas indicated horse-power and the water horse-power in the log includes all the work given up by the steam except a part of the frictional losses.

The average range of temperature of the jacket water was only about $7\frac{1}{2}$ degrees. An error of one degree would affect the amount of heat accounted for in heating the jacket water by more than 13 per cent. In reading the water intake and discharge thermometers, slight errors could easily be made, although the thermometers were carefully calibrated and corrections made. It was found that the horse-power shown by the gas compression cards plus the heat energy given up to the jacket was 1.007 times the indicated horse-power from the steam cylinders. This is in part due to the lag in the transfer of heat from the gas cylinder to the jacket water, and in part to the fact that the thermometers could not be read with absolute accuracy, for the reason explained above. It is probable that the friction

unaccounted for amounts to from 5 to 7 per cent. of the steam indicated horse-power.

7. *Volumetric efficiency.*

It is impossible to arrive at reliable results regarding volumetric efficiency except by actual measurements of volume of gas pumped as compared with the displacement of the compressor pistons. Even then if the range of revolutions per minute and pressure pumped against varies widely, as in this test, it will be difficult to select a set of cards that will be representative of average conditions.

The volumetric efficiency as shown by the right gas cylinder cards for 4.00 P.M. is as follows

Crank end	96.0
Head end	93.3
Mean	94.6%

The high volumetric efficiency from the cards of the left-hand gas cylinder is undoubtedly due to leakage past the piston, on account of the scoring of the cylinder previously referred to The results from the left side cards are as follows:

Crank end	102.6
Head end	103.2
Mean	102.9%

If we assume that the leakage in the right gas cylinder was too small to be appreciable, it follows that the leak on the other side amounted to $102.9 - 94.6 = 8.3$ per cent. of the volume of cylinder displacement. This was for atmospheric pressure only. As the piston advances, the leakage increases, and at 50 lb. pressure per square inch, above the atmosphere, the cards show that the volume of gas discharged from the left cylinder is only 90 per cent. of that discharged from the right cylinder, and this in spite of the fact that it started with 108.3 per cent. of the volume of gas shown by the right cylinder at atmospheric pressure.

From these figures the impossibility of accounting for the volumetric efficiency as found by measurements from a gas holder can be realized. Another difficulty is the fact that the temperature of the gas as it enters the cylinder is unknown. The temperature of the gas in the suction pipe was 79.9 degrees fahr., and that of the compressed gas 238 degrees fahr. The gas had to enter through the piston, and as it passed through the valve it undoubtedly was heated considerably. The piston is not water cooled and may become heated to a temperature approximating

that of the compressed gas. This can be seen if we assume the probable mass of iron in the piston and the cooling necessary to raise the temperature of the gas. The cylinder is $28\frac{1}{4}$ in. in diameter. If we assume a disk of cast iron 2 in. thick as representing the mass of the piston, it will contain about 1 250 cu. in., and weigh about 340 lb. The specific heat of cast iron is about 0.13, and the computed specific heat of the gas at constant pressure is 0.325. Now the weight of cast iron times the specific heat of cast iron times the range of temperature through which the iron is cooled is equal to the weight of gas times the specific heat of the gas times the range of temperature through which the gas is heated. If we assume that the gas was heated to a temperature of 200 degrees fahr. from the suction temperature of approximately 80 fahr., the range of temperature for the gas is 120 degrees. Then 340×0.13 (range of temperature for cast iron) $= .4 \times 0.325 \times 120$. From this equation the range of temperature for the iron is found to be 0.35 fahr. This shows that the mass of the piston would only need to be cooled 0.35 of a degree fahr. to heat the gas to 200 fahr.

Now the volume of a gas varies inversely as the absolute temperature. The absolute temperature for the suction gas is $461 + 80 = 541$, and the absolute temperature of the gas in the cylinder at approximately atmospheric pressure is, according to the above assumption, $200 + 461 = 661$. Then $541 \div 661 = 0.818$.

In the left cylinder the loss by leakage has been shown to be 18.3 per cent., so that the volumetric efficiency is reduced to 81.7 per cent. This averaged with 94.6 per cent. for the right cylinder gives a mean of 88.1 per cent.

Correcting for temperatures we have, $0.818 \times 0.881 = 0.721$, or 72.1 per cent.

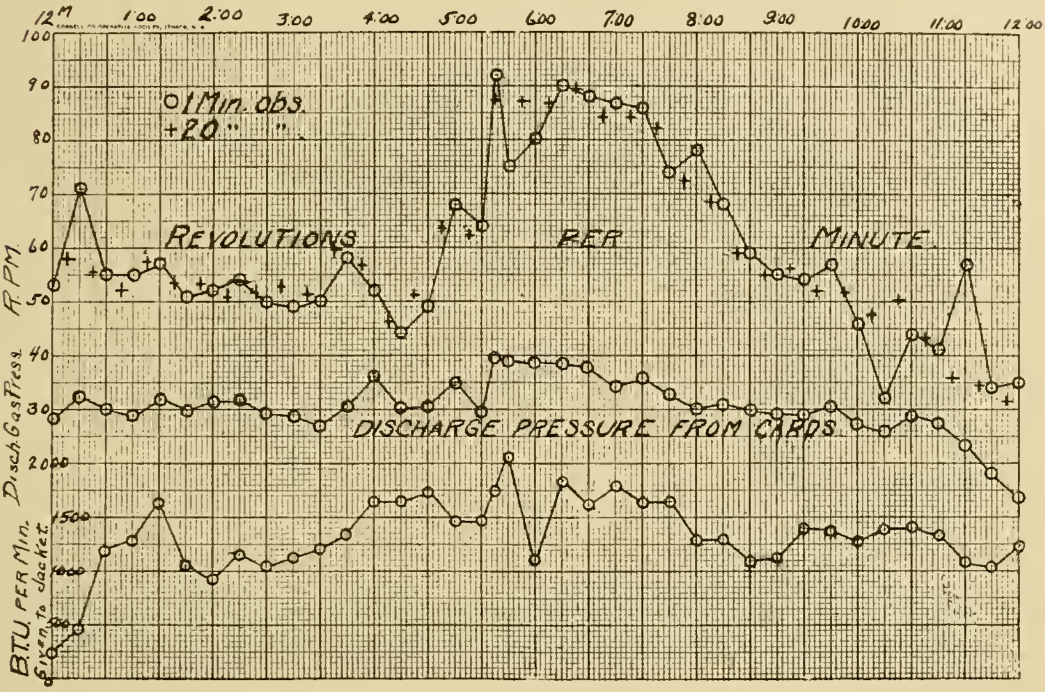
The volumetric efficiency found by actual measurements was about 65 per cent. The above method of computing is, of course, crude and unsatisfactory, as the temperature of the gas that fills the cylinder is unknown.

8. *Steam rate.*

An attempt was made to compute the amount of steam used per i. h. p. hour from the indicator cards taken at 6.40 P.M. While it is easy to determine the volume of steam as shown by the cards, it is known that a large part of the steam is condensed in the cylinders and, therefore, the value of the diagram factor is in doubt. Under the circumstances the results amount only to an intelligent guess. It is believed that the diagram factor was

not far from 0.65, and on this basis the steam per i. h. p. hour amounts to 29.4 lb. It is of interest to note that the builders of the compressor give 28 lb. as the steam rate.

The principal results have been arranged in graphical logs.



Taking into consideration the widely varying conditions and the condition of the compressor, the results are highly satisfactory.

I am greatly indebted to Mr. Jas. M. Robert of the faculty of the College of Technology of Tulane University of Louisiana for valuable assistance in making this test and to the senior class in the mechanical-electrical engineering course for taking observations and for computing the results.

[NOTE. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by October 1, 1909, for publication in a subsequent number of the JOURNAL.]

THE PANAMA CANAL.

By Frederic P. Stearns, Member Boston Society of Civil Engineers.

[Read before the Society May 5, 1909.]

President Roosevelt, in December, 1908, appointed a board of seven engineers to accompany William H. Taft, the President-elect, to the Isthmus of Panama to look into the condition of the canal work, and especially to report upon the feasibility and safety of the Gatun Dam.

The party sailed from Charleston, S. C., on the armored cruiser *North Carolina*, on January 25, 1909, and reached the Isthmus four days later. It spent ten days examining the work in progress and the plans and then returned via New Orleans to Washington and there made its report to the President on February 16, 1909.

The primary purpose of this meeting is to give an account of the visit to the Isthmus and the results of observations made during the visit. It is desirable, however, in view of the many criticisms that have appeared in the daily press since November last, to devote a part of the time to discussing the type of canal and replying to a part of these criticisms.

Another reason for devoting a part of the time to a discussion of the type is that many people, including many engineers who have not been to the Isthmus and who have not looked carefully into the question, naturally suppose that a sea-level canal is the best type for that place and that a mistake is being made in constructing a canal with locks.

An ideal sea-level canal, 500 ft. or more in width and of sufficient depth to float, with plenty of water under the keel, the largest steamers, and without locks or other obstructions, is an interesting conception. Such a canal, under the title of "The Straits of Panama," is the subject of Mr. Bunau-Varilla's frequent and lengthy communications, when he is not criticising the plans of others; but those who are not dreamers know that such a canal would make very great and unnecessary drain upon the national treasury and would, before its completion, not only exhaust the patience of the American people and of Congress, but would defer too far into the future the time for passing our navy and the commerce of all nations from one ocean to the other.

Every commission charged with a consideration of the type

of canal has put aside any such impracticable suggestion as a wide sea-level canal without a lock, and has reached the conclusion without dissenting votes that the most practicable sea-level canal would require a lock at its Pacific end and would have a bottom width not exceeding 150 ft. in portions excavated in earth, where the banks would be sloped; and 200 ft. in rock, where the sides below the water level would be nearly vertical.

The large amount of excavation is not the only great problem connected with the construction of the sea-level canal. The Chagres River and many smaller streams which would empty into such a canal must be controlled by dams and diverted by parallel canals on both sides of the main canal before the construction of the latter for a large part of its length could be begun, and these streams would make the construction more difficult throughout substantially the whole length of the canal.

It would be necessary for all time to maintain these diversion canals, which would be very expensive, or after the completion of the sea-level canal to allow the streams to flow into it and produce currents which would be detrimental to navigation.

The lock canal, while it has the admitted disadvantages of locks, so raises the level of the water for nearly the whole distance across the Isthmus as to make it feasible to provide wide channels for navigation at a comparatively moderate expenditure of time and money, and solves in a most satisfactory manner the problem of the floods in the Chagres and other streams, without the construction of any dams in addition to those necessary for canal purposes.

In the comparisons which I will make between the lock canal and the sea-level canal, I will in all cases, unless otherwise stated, refer to the narrow sea-level canal recommended by the majority of the Board of Consulting Engineers in 1906; that is, to the canal that has a bottom width of 150 ft. in earth and 200 ft. in rock.

Colonel Goethals, the chairman and chief engineer of the Isthmian Canal Commission, has recently made careful estimates of the cost of the lock type of canal now under construction, including several changes from the original plan, such as increased size of the locks, the widening of the canal from a minimum of 200 ft. to a minimum of 300 ft., and the moving of the locks at the Pacific end of the canal back several miles from the coast, where they can be more easily defended.

On account of these changes, and for other reasons which will not be mentioned now, the estimated cost of the canal has

been greatly increased above the original estimate and is now placed at $375 000 000. It is estimated that this sum will be diminished $15 000 000 by money returned to the United States Treasury, but for the present purposes I will assume $375 000 000 as the total outgo for the acquisition and construction of the lock canal.

His corresponding estimate of the cost of the sea-level canal is $563 000 000.

According to these estimates, which are based on more complete information, both as to the quantities of work and the cost of doing the work, than any previous estimates, the narrow sea-level canal would cost $188 000 000 more than the wider lock canal.

These figures do not include the interest on the money expended during the construction of the work, because such interest does not come out of the funds provided for the construction of the canal, but it does have to be paid by the people of the United States and is no less a burden than a similar sum paid for construction.

The sea-level canal would require six years longer for its construction than the lock canal and during this additional six years the interest account, on the basis of 3 per cent. annually, would be $93 000 000.

The difference in the estimated cost, therefore, including interest during construction, is $281 000 000, and the corresponding difference in the fixed charges, reckoned upon a 3 per cent. basis, would be $8 400 000 annually.

In comparing the two types of canal from the standpoint of navigation, I believe that the advantages of the wider channels of the lock type of canal much more than offset the disadvantages of the locks, and that the lock canal will permit ships to pass from ocean to ocean with greater safety than the sea-level canal, and have a greater capacity for traffic.

The time required for ships to go from ocean to ocean varies with the size of the ship and other conditions, but will be approximately 12 hr. with either the sea-level or the lock canal. There would be a difference of an hour or two in favor of the sea-level canal with a small traffic, and a corresponding advantage for the lock canal with a large traffic.

This relative difference in time with different amounts of traffic may need explanation. In a narrow canal it is necessary to follow the precedent furnished by the Suez Canal, where, when two ships are to pass one another, one is made fast at a mooring place and the other passes at half speed.

A theoretical investigation shows that if one ship only passes another made fast, the number of stops in the passage of the canal varies as the square of the number of ships passing in a given time; for example, if four ships passing through the canal in a day require on an average one stop per ship, eight ships per day passing would require four stops per ship; and sixteen ships, sixteen stops per ship.

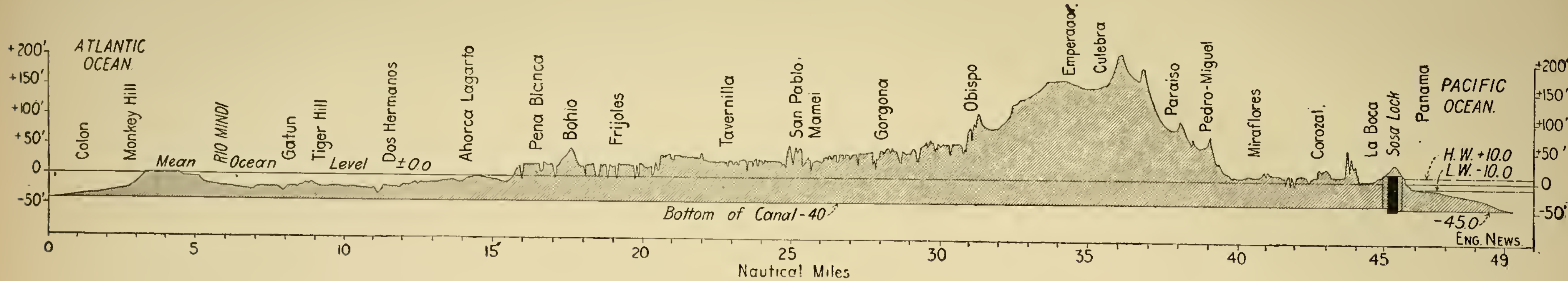
In practice better results are obtained by having two or more ships pass in succession the one made fast, but increasing traffic necessarily increases the time required to pass through a canal which is so narrow as to require tying up to permit the passing of ships, and finally, the delays due to stops become so great as to limit the capacity of the canal, just as the capacity of a single track railroad with occasional turnouts is limited.

The difference in the time required to pass through the canal is not enough to have any important bearing upon the selection of the type, and we may revert to the more important questions of safety of transit and capacity of canal; but before taking up these questions I will describe briefly the design of the lock canal, as it is now planned, and compare it with the sea-level canal recommended by the majority of the Board of Consulting Engineers of 1906.

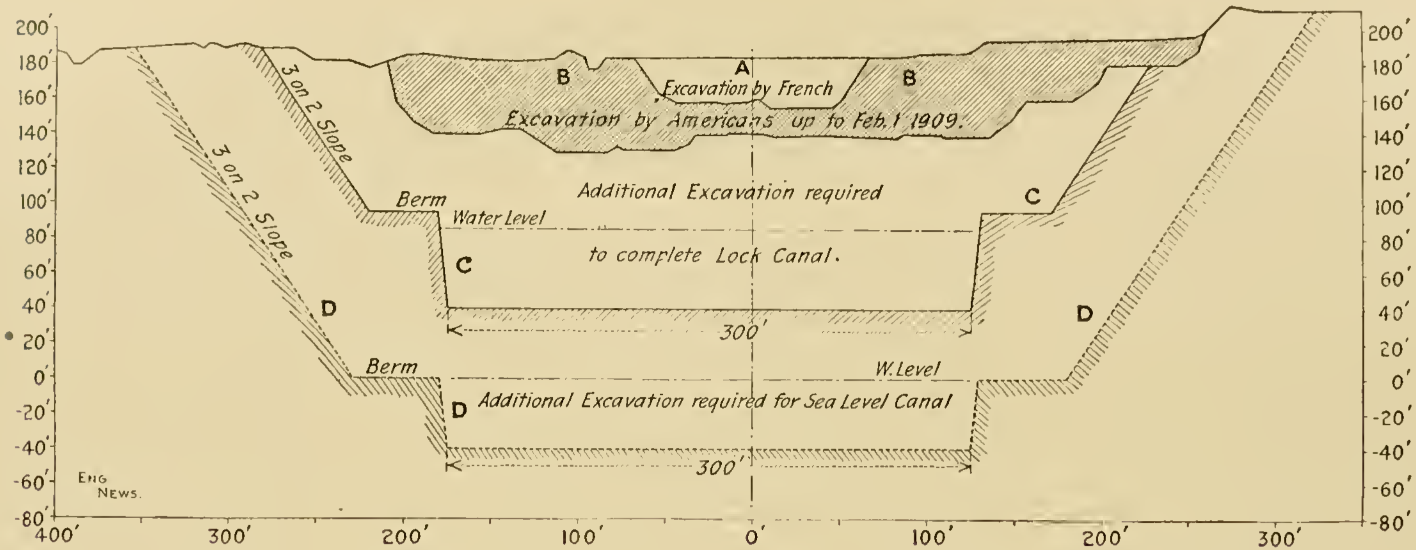
Beginning the description at the Atlantic end of the canal, the first 4½ miles are a dredged channel in Limon Bay, which is to be protected by a very extensive breakwater located at its entrance. This channel is to be 500 ft. in width and is to be continued with the same width 2½ miles further inland to the locks required to raise and lower vessels into and from the great lake which will be created by the Gatun Dam.

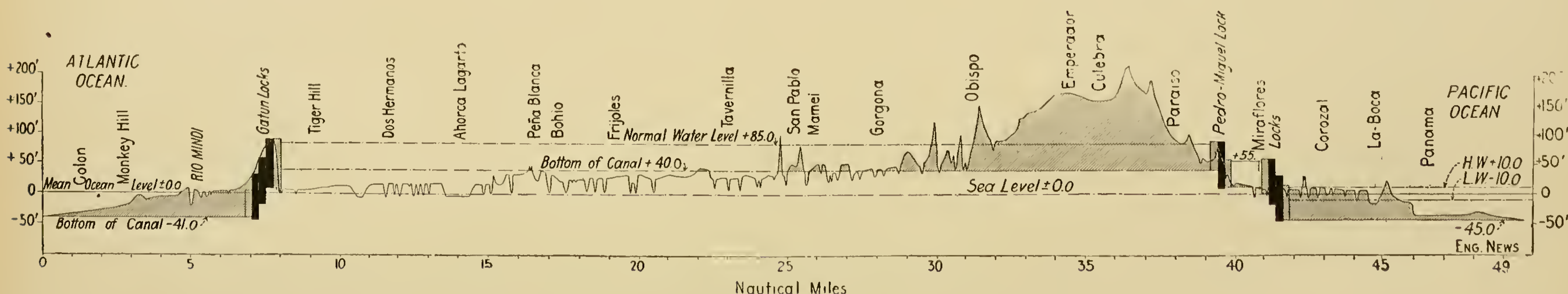
The surface of the lake is to be 85 ft. above the sea level, and ships will be raised to and lowered from this height by passing through three locks of equal lift, each 1 000 ft. long by 110 ft. in width, and constructed in duplicate so that if one set should be out of order the other can be used.

From the locks at Gatun to Obispo, a distance of 23 miles, or more than half of the distance across the Isthmus, ships will have the benefit of lake navigation. The depth of water over the low land near the dam will be from 70 to 75 ft., and nowhere in the 23 miles is the depth to the bed of the river less than 45 ft. The deep channel of the river, however, follows a somewhat tortuous course, but only a small amount of excavation is required in the upper portion of the lake to create channels on straight courses not less than 500 ft. in width at the extreme upper end, and 1 000 ft. wide at points farther down.



Figures show Contour Elevations


Excavation by French
Excavation by Americans up to Feb. 1 1909.
A
B
B
3 on 2 Slope
3 on 2 Slope
Additional Excavation required
to complete Lock Canal.
Berm
Water Level
C
C
D
D
D
300'
Berm
W. Level
Additional Excavation required for Sea Level Canal
300'
ENG NEWS.


ATLANTIC OCEAN.
PACIFIC OCEAN
Colon
Monkey Hill
Mean Ocean Level ±0.0
RIO MINDI
Bottom of Canal -41.0
Gatun Locks
Tiger Hill
Dos Hermanos
Peña Blanca
Bohio
Frijoles
Normal Water Level +85.0
Bottom of Canal +40.0
Tavernilla
San Pablo
Mamei
Gorgona
Obispo
Culebra
Paraiso
Sea Level ±0.0
Pedro-Miguel Lock
+55
Miraflores Locks
Corozal
La-Boca
Panama
H.W.+10.0
L.W.-10.0
-45.0
ENG. NEWS
Nautical Miles

The next 8 miles of canal pass through the Culebra Cut to the Pedro Miguel Lock, and here in the deeper cutting the canal is to be 300 ft. wide and 45 ft. deep. At Pedro Miguel there are to be twin locks having a single lift, and ships passing towards the Pacific will be lowered at these locks about 30 ft. into a small lake, through which they will pass for about a mile and a half to twin double lift locks at Miraflores, about 4 miles from the shore, and there be lowered into a channel 500 ft. wide extending to deep water in Panama Bay.

The sea-level canal has a channel with a 500-ft. bottom width in Limon Bay and of 300-ft. bottom width in Panama Bay, but for the whole distance across the Isthmus between the shore lines it has bottom widths of 150 ft. in earth and 200 ft. in rock, as already stated.

There is another material difference between the two canals. The sea-level canal follows a curving course for 19 miles out of the 40 miles from shore to shore, or, in other words, for substantially half its length. On the lock canal curved channels are avoided entirely, and changes in direction are made by large widenings at points of intersection. The lock canal, therefore, follows the precedent set in harbor engineering generally and in the canals connecting the great lakes.

The navigation through the 23 miles of Gatun Lake may be best understood by comparing it with the navigation in the important harbors of the country. It would be similar to the navigation through the 10 miles of Boston harbor, extending from the Graves up to the city, except that the channel depths at the Isthmus will be much greater than in Boston harbor, and there will be an absence of currents.

What would the navigation interests in Boston say were it proposed to substitute for such channels as now exist a canal curving for half its length and having a bottom width of 150 ft.?

The passage of the locks may seem a matter of much difficulty to people who are not acquainted with their operation. It has, however, been shown to be a simple matter by the experience at the St. Mary's Falls Canal, where a traffic greater than that which passes through any other canal in the world passes through its locks without accident or delay.

It is easy to see that there will be less difficulty in taking ships into the locks at Panama than into the docks which they usually enter, because the very long piers at the approach to the locks are in the line of the course of a ship, and it is not necessary to turn the ship at right angles to its course in order that it may come alongside of the pier.

At the locks there will be no strong currents such as those that interfere with the docking of ships on the Hudson River front in New York, and it is also true at Panama that the prevailing winds are in the direction of the length of the locks.

When a ship is in the lock it is raised or lowered without difficulty, and the movement into the next lock is only a repetition of the first operation.

There is much statistical material relating to the operation of locks and canals, and it shows clearly that injury to vessels occurs from the grounding or sinking of the vessel in the canals, and does not occur when they are moving slowly into and out of the locks. The statistics show that with wider channels such accidents are less likely to occur.

The Suez Canal in 1886 had a bottom width of 72 ft. and a depth of 26 ft., and the records show that in that year 188 ships, equal to 6.1 per cent. of the whole number, grounded while passing through the canal. In 1900, after the canal had been enlarged, the number of ships grounding was 65, equal to 1.9 per cent. of the whole number for the year. Further widening and deepening of this canal are now in progress.

In the wider channels between lakes Superior and Huron connected with the St. Mary's Falls Canal, although the traffic is several times greater than on the Suez Canal, the percentage of groundings is about one nineteenth of the percentage in the Suez Canal, or about one fifth of such percentage, after making due allowance for the difference in the length of the channels.

It is obvious that the wide channels of the lock canal will have a greater capacity for traffic than the narrow channels of the sea-level canal, and it is, therefore, necessary to make the comparisons only between the locks of the lock canal and the channels of the sea-level canal.

Careful computations made by engineers who have had long experience at the St. Mary's Falls Canal show that the capacity of the locks at Panama will be not less than 80 000 000 tons annually. This is six times the tonnage which passes through the Suez Canal and seventeen times the tonnage passing in and out of Boston harbor to and from foreign ports. In all of these statements, the traffic in both directions is included. So great a traffic could not be passed through the narrow sea-level canal.*

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* One of the official publications relating to the Suez Canal gives the details of movements of ships in the canal on the 3d of January, 1908. The movements were substantially equivalent to eleven ships passing the whole length of the canal in a southerly direction, and seven ships passing

The tonnage through the Suez Canal increased in the 37 years from 1870 to 1907 somewhat uniformly from a very small beginning to 15 000 000 tons annually. Unless there is a greater traffic through the Panama Canal than through that at Suez, the capacity of the lock canal will be sufficient to meet all requirements for a very long time in the future — very likely for a century or more.

I have attempted to tell you in a summary way the salient points of difference between a lock canal and a sea-level canal: how even the narrow sea-level canal will cost, by the latest estimates, including interest during construction, $281 000 000 more than a lock canal; that it will require an additional six years to make the sea-level canal available for use; that the lock canal will be safer for the ships passing through it and have a greater capacity for traffic than the sea-level canal.

These are the main reasons why the lock canal is preferable to the proposed sea-level canal, and a wider sea-level canal would require still more time and money.

There has been, however, so much space given in the press, especially in New York, to criticisms of the type of canal now under construction that I will notice a few of the principal points which have been urged against this type. It is stated:

(1) That the Gatun Dam is to be built on permeable and unstable foundations and will, therefore, be unsafe.

(2) That the estimated cost of the lock canal is so far above the original estimate that it is nearly the same as the cost of the sea-level canal, so that the cost is not now an argument against a sea-level canal.

(3) That so much more rapid progress than was anticipated has been made in excavating the canal that the sea-level canal can be completed nearly as soon as a lock canal.

(4) That the size of the locks will limit for all time the size of the ships which can pass through the lock canal.

(5) That earthquakes may destroy the dams, locks and regulating works of the lock canal and interfere with the operation of the gates.

In answering the criticisms of the foundations of the Gatun Dam, I cannot do better than to ask you to make a comparison

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in a northerly direction, making a total of eighteen ships. The tonnage of these ships is not given, but assuming them to be equivalent to the average for the year, they would represent a total of 22 000 000 tons annually, or about one fourth of the capacity of the lock canal at Panama. The total number of stops to enable one ship to pass another was 1.7 per ship, and the length of a stop averaged about 1 hour.

of the weight of authority that pronounces in favor of and against the sufficiency of the foundations.

The board of engineers who recently visited the Isthmus included in its number, in addition to the speakers of this evening, our fellow-member, Mr. John R. Freeman, whose absence to-night I regret. It is unnecessary to state to the members of this Society, who know so well his eminence as a hydraulic engineer, that he is amply qualified to give a sound opinion upon this question.

Other members of the board, not personally known to many of you, who stand at the head of the list as designers and constructors of dams, are Mr. Arthur P. Davis and Mr. James D. Schuyler. Mr. Davis, as the chief engineer of the Reclamation Service, has had occasion to take part in the design, construction and maintenance of more dams of nearly all types than any other engineer in the country.

Mr. Schuyler has built great masonry dams, but his specialty is the construction of high earth dams, built by the hydraulic fill process. He has written valuable treatises on dam construction, and contributed very valuable papers on the subject to the American Society of Civil Engineers.

Mr. Isham Randolph, another member of the Board, is best known from his position as chief engineer of the great Chicago drainage and ship canal. In connection with the original construction and later in the extension of the canal for the development of power, he has had occasion to build extensive dams and regulating works, and he is fully qualified to give a sound opinion on dam construction.

In addition to the members of the recent Board, Mr. Alfred Noble, an engineer at the head of his profession, who has had much experience in the design, construction and operation of canals, and who has been associated with extensive dam construction, and Mr. Benjamin Harrod, whose opinion is of especial value because of his twenty-six-year connection with levee construction on the Mississippi River, have testified to the safety of the Gatun Dam.

Last but not least I will mention the engineers in charge of the work on the Isthmus, who are intimately acquainted with the ground on which the dam is to rest and with the results of the investigations of the site, and they believe the foundations and the dam to be entirely safe, both the present chief engineer, Colonel Goethals, and his predecessor, Mr. John F. Stevens, having testified to this effect.

Those who have made the strongest assertions that the dam would not be safe, have been given the most space in the public

press and have done the most to cause uneasiness in the mind of the public are in some cases not civil engineers, and in other cases they are civil engineers whose experience has not included hydraulic work or dam construction. As a rule, they have had some project of their own, and seek to advance their own project by denouncing the various features of the lock type of canal.

There are a few others whose opinions should have value who oppose the construction of the dam, but the evidence as a whole is overwhelmingly in favor of the safety of the dam. Those who criticise the foundations of the dam refer in their remarks to the portions of the foundation where gorges 200 ft. or more in depth were at some time in the past eroded in the rock and subsequently filled with deposits of alluvial material, generally of a clayey character.

The alluvial material has been thoroughly investigated by test pits and borings made under the direction of Mr. Caleb Mills Saville, a member of our Society, whom many of you know well.

Your attention is especially called to a pit sunk under his direction in the middle of one of these alluvial deposits to a depth of 90 ft. below the surface of the ground and 80 ft. below sea level. The first 36 ft. was excavated in a sandy clay which was so nearly impermeable that only from 20 000 to 25 000 gallons of water per day had to be pumped from the pit to keep it dry. Those of you who are connected with water-works construction will realize what a very small flow this quantity of water represents.

In sinking the pit the remaining 54 ft., no additional water was encountered, showing that the material below the sandy clay was impervious.

I will not weary you with other details, but will state that the investigations prove clearly the satisfactory character of the foundations as regards watertightness and stability. It is of course recognized that clay has not the same degree of stability as sand and gravel, but by spreading the base of the embankment, stability can be secured, and this has been done in the present designs.

The high earth dams built in the West have generally slopes of 3 horizontal to 1 vertical, or steeper slopes. A dam at Gatun with 3 to 1 slopes and the usual elevation above water level would have a base about 600 ft. thick at sea level, while the design which has been adopted has a base of 2 100 ft. in thickness.

Those who state that the great increase in the present estimated cost of the lock canal above the original estimate brings its cost substantially as high as that of a sea-level canal

use the original estimate for the sea-level canal without making additions corresponding to those made in increasing the estimate of the lock canal.

With some exceptions, the same causes which have operated to increase the estimated cost of the lock canal have also operated to increase the estimated cost of the sea-level canal, and there is no better basis for obtaining the relative cost of the two than that furnished by the recent estimates of Colonel Goethals. One has only to look at the relative profiles of the required excavation of the lock and sea-level canal to appreciate how much more excavation is required for the latter.

The third criticism, that much more rapid progress than was anticipated has been made in excavating the lock canal, and that with such rapid progress in excavation it would not take many years to excavate the additional amount of material required for the completion of the sea-level canal, fails to take into account the effect upon the speed of excavation of the Chagres River and other streams, which would enter the canal at points far above sea level.

The Chagres River, where it first meets the line of the canal, when at its ordinary height, is 45 ft. above sea level. On one occasion during our recent visit, there was a flood which raised its level at this point 22 ft., or to 67 ft. above sea level. Much higher floods have occurred.

The bottom of the Culebra Cut in the lock canal as planned is only 5 ft. lower than the ordinary level of the Chagres River at the point mentioned. At the time of the flood nine steam shovels were excavating for the canal channel alongside the Chagres River, some of them behind dikes and others opposite portions of the river somewhat further down stream where the ordinary water surface was below the level of the bottom of the canal. Even under such conditions, these nine shovels were put out of commission for a time.

The bottom of the sea-level canal would be 85 ft. lower than that of the lock canal, and it is inconceivable that any considerable amount of excavation could be done either by steam shovels or dredges on the 13-mile stretch of canal from Bohio, where the river is at sea level, to Obispo, where it is 45 ft. above sea level, in advance of the control of the Chagres River and its tributaries by the construction of the Gamboa and other dams, and by diversion channels on both sides of the canal, extending at least to tide water in the river.

The only practicable way to build the dam proposed, in

connection with the sea-level canal at Gamboa, is to first provide a diversion channel, excavated in rock, through which the Chagres River may flow during the construction of the main dam, this channel to be subsequently closed by the construction of a masonry dam with the necessary regulating works.

In such a diversion channel it would be necessary to build a considerable amount of preparatory masonry work before diverting the river in order to facilitate the subsequent construction of the masonry dam. This plan is being followed at Gatun, where a channel 300 ft. in width has been excavated, and where the laying of the concrete has recently been begun.

It will require more than three years, probably three and a half years, from the time that Congress authorized the construction of the Gatun Dam before the Chagres River will be diverted through the diversion channel. The required diversion channel at Gamboa is longer and deeper than that at Gatun, so that its completion would require not less than three or four years.

The next step at Gamboa, after the diversion of the river, would be the excavation through porous earth to bed rock, a depth of about 60 ft. below the river bed. The proposed dam at this point would be carried to 190 ft. above its base, and, if built of masonry, both the excavation and the structure would be much like the Wachusett Dam at Clinton, except that the Gamboa Dam is much longer and would contain much more masonry.

The dam at Clinton required 5 years for its construction after the diversion channel had been provided, and this is not too long a time to reckon upon for the Gamboa Dam, which would make a total of from 8 to 9 years for the construction of the diversion channel and the dam.

During this period all other diversion channels and dams required by the sea-level canal could be constructed, but it is only after this period of 8 years that satisfactory progress could be made in excavating the canal between Bohio and Obispo.

There need be no cessation of work in the Culebra Cut for the construction of the sea-level canal if a sufficient dam were to be provided to prevent the Chagres River from entering the cut at its northerly end and sufficient pumping machinery were to be provided to keep the cut free from water when it became too low to drain by gravity, but the excavation from low levels would be greatly retarded because the material could not readily be hauled out except at the Pacific end, and the cut would become so narrow that the number of steam shovels and tracks would be restricted.

Believing that the lock canal can be completed in less than 6 years, that the Gamboa diversion channel and dam would require 8 or 9 years for their completion, and that the bulk of the excavation for the 13 miles from Bohio to Obispo would have to be made after the completion of the dam, I am firmly of the opinion that 6 years is the least additional time which should be allowed for the sea-level canal.

The criticism that the size of the locks would limit for all time the size of the ships which can pass through the canal is not warranted. It now seems highly improbable that any war ships or any commercial ships which will require to pass through the Panama Canal will be constructed in the next 25 or 50 years of a size which will not pass through the mammoth locks now under construction, but if the size of ships should continue to grow as it has for many years in the past, it would be feasible to construct larger locks to accommodate them at a small fraction of the additional cost of the sea-level canal; or, if it should be found necessary at some time in the future to dispense with locks, the lock canal can be transformed by widening and deepening, and without interrupting traffic, into a wide and deep sea-level canal. This view was accepted by the thirteen members of the Board of Consulting Engineers of 1905–1906 without a dissenting vote.

The interest on the excess cost of constructing a narrow sea-level canal at the present time would in 40 or 50 years pay for the cost of such transformation to a sea-level canal having a minimum width of 500 ft. and a depth of 45 ft.

The criticism relating to the effect of earthquakes on the dams, locks and regulating works of the lock canal is a groundless one, in so far as it affects the type of canal, because the sea-level canal also has dams, locks and regulating works.

There is nothing in the written history of the Isthmus to indicate that severe earthquakes have occurred, and the masonry of old churches, including the flat masonry arch which is still standing in one of them from 150 to 200 years old, furnishes strong evidence that no severe earthquakes have occurred.

The masonry of these churches, built of rubble and lime mortar, has little stability in comparison with lock walls built of Portland cement concrete. These lock walls are extremely massive structures, some of them being as much as 60 ft. in thickness.

At the time of the San Francisco earthquake, the fault line where the movement was greatest passed through and near several high earth and masonry dams when the reservoirs were sub-

stantially full of water without doing any serious injury. There is no reason to expect different results at the Isthmus, even if an earthquake as severe as that at San Francisco should occur.

It is annoying, especially to those who are working with the utmost energy in the tropics to construct the canal which has been authorized and directed by Congress, to have this constant fire of criticism of the work which they are doing and of the type of canal which they believe is the proper type to be used at the Isthmus.

There is no question but what the lock type of canal is to be built at Panama.

I cannot do better in closing than to quote from President Taft's recent answer to the Panama Canal critics. After stating that the lock type of canal will cost less, require less time for construction and be a safer canal than the proposed sea-level canal, he concludes in these words:

"For these reasons the administration is proceeding to construct the canal on the type authorized and directed by Congress, and the criticisms of gentlemen who predicate all their arguments on theory and not upon practical tests, who institute comparisons between the present type of canal and the sea-level type of 300 to 600 ft. in width that never has been or 'will be on sea or land,' cannot disturb the even tenor of those charged with the responsibility of constructing the canal, and will only continue to afford to persons who do not understand the situation and are not familiar with the history of the canal and of the various plans proposed for the canal, an unfounded sensation of regret and alarm that the government is pursuing a foolish and senseless course. Meantime the canal will be built and completed on or before the 1st of January, 1915, and those who are now its severest critics will be glad to have their authorship of recent articles forgotten."

[NOTE.— Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by October 1, 1909, for publication in a subsequent number of the JOURNAL.]

LOCATION OF PIPES AND CONDUITS FOR PUBLIC SERVICE CORPORATIONS.

By Lewis M. Hastings, Member Boston Society of Civil Engineers.

[Read before the Society, February 10, 1909.]

The importance of suitable locations for pipes and conduits in the public highways of a modern city is becoming more fully realized by city officials as the number of such locations applied for increases. With this incidentally comes the necessity for preserving in some convenient form for future use the records of location already granted and the positions of such structures as they may be uncovered and located from time to time. In many cities great confusion and needless expense have been caused in the construction of public work by lack of knowledge or faulty records of the work already placed in the public streets.

In Cambridge, very much of the responsibility for the proper location of these structures is placed upon the city engineer, as is shown by the general provisions of Section 2 of the city ordinances relating to the engineering department, which follows:

Engineering.

" Section 2. The city engineer shall exercise a general supervision of all matters within said department; he shall be consulted in relation to public improvements of every kind where the advice of a civil engineer would be of service. He shall have the charge of all plans of streets, drains, sewers and structures of every kind not especially belonging to other departments, and shall keep the same properly classified and indexed, and he may make such rules and regulations concerning the taking of plans from his office as he may deem necessary to insure their safety."

In locating sewers in the city, somewhat large powers are given to the city engineer, as will be seen from the following extract from the ordinance relating to sewers, Section 2.

Sewers. Chapter 23.

" Section 2. Whenever any street is opened for the laying of pipes for water, gas or other purposes, or for the prosecution of any work of construction, such laying of pipes and the work connected therewith, such work of construction, shall be so

executed as not to obstruct, in any way, the course, capacity or construction of a common sewer, and whenever pipes for any purpose or any work of construction are found to exist at such a depth or in such location as to interfere with any existing sewer or with the building of any common sewer of the required size and at the proper depth and grades, the department, corporation or person maintaining the same shall, upon notice thereof, at once remove, change or alter said pipe or pipes or other works in such a manner as the city engineer may direct. If such department, corporation or person neglects to comply immediately with the terms of such notification, the city engineer may make such removal, change or alteration, and the cost thereof shall be paid by such department, corporation or persons."

While this section may sound somewhat arbitrary, it has, in fact, been found of very great service in securing the proper locations for sewers in overcrowded streets, and as a matter of fact, the extreme power given to the city engineer by this ordinance has never, I think, been exercised, all the corporations and departments to which it applies recognizing its necessity and acquiescing in its provisions. In this way the moral effect of the ordinance has been useful.

That specific location of the structures of the public service corporations might be more definitely determined before construction was begun, and records of the location of structures as actually built obtained, the following section of an ordinance relating to streets was passed.

Streets.

"No gas pipe, water pipe, sewer conduit, street railway track, pole nor any other structure, except wires, shall be placed beneath, upon or above any public street or way except upon a location and at a grade approved by the city engineer or authorized by the board of aldermen. Within sixty days after the completion of the work so approved or authorized, a final plan showing accurately in detail the lines, grades and construction of the work as finished shall be filed in the office of the city engineer. If required by the city engineer, a preliminary plan showing the proposed location and grade of the structure shall first be filed in his office.

"Any person violating the foregoing provisions shall be subject to a penalty of $20 for each offense and shall remove any structure placed contrary to the provisions of this section if required so to do by the city engineer, and upon failure to do so

the city engineer may make such removal or change and the cost thereof shall be paid to the city by the person or department owning or controlling the structure."

Subject to the general provisions of the above ordinances the corporations desiring locations in the city streets first petition the board of aldermen for such locations, filing with the petition a preliminary plan showing the general location desired, which has been prepared after consultation with the city engineer and agreement upon the general location. This is referred to the committee on highways, who give hearings and consider the matter more or less carefully and make such report as seems for the public interest.

If the report is favorable an order is reported granting the location.

If the location applied for is for a street railway track, the order granting to the West End Street Railway Company, who still own the track and real estate leased to the Boston Elevated Railway Company, the location desired, contains the following provisions, viz.:

WEST END STREET RAILWAY COMPANY.

" The right to lay down tracks located by this order is given upon the condition that the entire work of laying down the tracks, the precise location of the same, the form of rail to be used and the kind and quality of materials used in paving said tracks and on either side of the same shall be under the direction and to the satisfaction of the mayor, the city engineer and the superintendent of streets, and shall be approved by them.

" Also upon the further condition that said West End Street Railway Company shall accept this order of location and agree in writing to comply with its several conditions and file such acceptance with the city clerk within thirty days from the date of its passage, and also before proceeding to construct said tracks shall file for record with the city engineer, location plans and profiles of said tracks, which show the same in detail, together with the sidings, turnouts and connections."

If the location granted is to the Cambridge Electric Light Company for ducts or conduits, the order contains the following provisions, viz.:

CAMBRIDGE ELECTRIC LIGHT COMPANY.

" 1. The kind and quality of material used in the construction of said duct or conduit and exact location shall be under

the direction and to the satisfaction of the city engineer and the superintendent of streets and shall be approved by them.

"2. The board of aldermen, having first given the company or its agents opportunity to be heard, if in the judgment of said board the interests of the public so require, or if each and all of the above conditions, terms and requirements are not complied with, may order such duct or conduit or any of said ducts or conduits in this city and the wires therein to be removed, and the company shall thereupon remove the same in conformity with such order, and if the company neglects to execute such order and to remove said ducts or conduits after thirty days' notice of such order, the board of aldermen may cause the order to be executed and such ducts or conduits to be removed, and the expense thereof the company shall repay to the city.

"The location herein named is indicated upon a plan furnished by said company and filed with the city clerk."

If the location granted is to the New England Telephone and Telegraph Company, the order contains the following provisions, viz.:

New England Telephone and Telegraph Company.

"In every underground conduit constructed by said company one duct not less than three inches in diameter shall be reserved and maintained throughout its entire length, free of expense, for the use of the fire, police and other telegraph and telephone signal wires belonging to the city of Cambridge and used exclusively for municipal purposes. The city shall have equal facilities with the company for putting in, taking out and repairing its wires and cables of said conduit system.

"The right is also reserved to the city to connect from any other conduit system or from distributing poles, pipes or buildings, either municipal or private, to the manholes constructed by said New England Telephone and Telegraph Company of Massachusetts for the purpose of carrying the said telegraph and telephone signal wires owned by said city from one system of conduits or poles to any other system of conduits or to other poles or buildings; provided, however, that said company, if it shall so elect, may construct, build or provide the other manholes at its own expense for the use of the city in making connections with the ducts reserved for municipal signal wires as aforesaid.

"2. The authority herein granted is also subject to the right and privilege of the city, if it shall so elect at any time, and it

shall have the right, to purchase of said company, its successors or assigns, all or any part of said conduits at a price not exceeding the original cost thereof, to be fixed, in case the parties cannot agree, by the Chief Justice of the Superior Court at the time. In case the Chief Justice declines to serve, it shall be fixed by three referees, one of whom shall be appointed by the mayor, one by the said company and the third by the two before mentioned, and by accepting the authority herein given, said company, for itself, its successors and assigns, does thereby agree to sell upon the aforesaid terms to the city aforesaid.

"Within six months after the completion of the construction of the conduits built under the authority conferred by this order, or whenever, during such construction, the mayor shall so request, said company shall file with the city clerk a statement, in such form as the mayor shall require, showing the original cost of said conduits, said statement to be certified by the president of said company.

"3. In case of purchase as aforesaid, said company shall thereafter have the right to use said conduits by payment to the city of such rental, in case the parties cannot agree, as said Chief Justice of the Superior Court or referees may determine.

"4. Said company shall construct said conduit system in such locations in the said streets as may be designated by the city engineer and to the satisfaction of the mayor, the superintendent of streets and the city engineer. Within three months from the time of completion of the said conduit system, said company shall file with the city engineer and city electrician satisfactory plans showing in detail the location, size, depth, appurtenances and details of construction of the systems as built. The time, manner, place and duration of the opening of streets for the construction of said conduits, and the time within which the work shall be completed, shall be under the direction of the superintendent of streets of said city. Whenever said company shall dig open any street for the construction, maintenance, operation or repair of any part of said system, it shall refill and repair said street to the satisfaction of the superintendent of streets. In constructing said conduit system, and in making repairs upon the same, it shall employ Cambridge labor, with the exception only of skilled men required in the work.

"5. That said company, while using any part of the conduit system authorized by this order, shall, so long as it shall pay no compensation for the use of the streets occupied by said conduit system, in whole or in part allow and remit to the city a

discount of $33\frac{1}{3}$ per cent. from the regular rates established for exchange service for the use of its telephones by others in this city, for and on account of all telephones and other patents of and used by said company for the sole use of the city.

. . . .

"7. The said company before beginning work under this order shall accept this order in form of written acceptance dated . . . ., now on file with the city clerk, and shall give to the city of Cambridge a bond which shall be satisfactory to the mayor, conditioned to indemnify and save the city harmless from and against all claims, damages, cost and expenses and losses whatsoever to which the city may be subjected in consequence of the acts and neglect of such person or corporation, their agents, officers and servants, and any and all persons acting by, through or under such person and corporation and in any manner arising from and in any way growing out of the construction, maintenance and operation of said conduit system under this order."

Having obtained its location or franchise, the company now proceeds to obtain the necessary data for an exact location from old records, plans or excavation on the spot of existing structures, pipes, etc. From these data a more careful location is then determined and the work carried out. When finished, complete plans are filed with the city engineer showing the location, depth and size of structures built under the order.

As is common in most of the older cities of the country, the data concerning the locations of pipes, conduits, etc., belonging to the city and private corporations have been found in many cases to be very meager and unreliable in character, besides being scattered and difficult to obtain.

In order that these data might be collected and put in available condition for use when needed, in settling the constantly recurring questions arising regarding the proper locations for these structures, some years ago a tracing copy of the streets of the entire city was made upon a scale of 40 ft. to an inch, upon which the structures, pipes, conduits, etc., are shown by lines and figures in appropriate colors. Nothing else is shown upon these sheets but this.

All data as fast as obtained are put upon these plans, thus making the plans of increasing value and usefulness.

[Note. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by October 1, 1909, for publication in a subsequent number of the Journal.]

METHOD OF OBTAINING AND PREPARING TRANSFERS OF PROPERTY FOR USE IN ASSESSORS' DEPARTMENT, LOWELL, MASS.

By Arthur Bartlett, Member Boston Society of Civil Engineers

[Read before the Society, February 10, 1909.]

In January, 1894, Mr. George A. Nelson, of the city engineer's office, read before this Society a paper describing in detail the methods employed in the survey for the city map of Lowell. This paper was published in the Society Journal for October, 1894, and can be referred to if a further description of plans or methods of survey is required.

The plans on file in the city engineer's office are on white mounted hot-pressed Whatman paper, 22 in. by 30 in., to a scale of 50 ft. to an inch. These sheets contain individual lots with their areas, dimensions and buildings, and, if the lot is a portion of a divided estate, the number of the lot as shown on the original subdivision of the estate. Copies of these sheets are made on Crane bond paper, showing lots, lot numbers and areas only, for the Assessors' Department. The names of the lot owners are then written in pencil as guides to the assessors in making their assessments on real estate.

During the first few years nothing was done to keep the sheets, already completed, up to date. In 1896 it was found that so many changes in real estate were constantly taking place that the plans and tracings were really unreliable for instant use. At this time the assessors were in the habit of sending two clerks to the Registry of Deeds to get all real estate transfers which they thought belonged to Lowell. These transfers, covering the years 1892 to 1896 inclusive, were turned over to the Engineer's Department as data for plan corrections. An examination of these records showed about 15 per cent. containing the necessary information, and it was thought best to talk things over. A conference was held between the principal assessors and City Engineer Bowers, and it was agreed that the Engineer's Department should obtain the real estate records in their own way, correct the plans and tracings and turn transfers and tracings over to the assessors correct to May 1 of the current year.

The following plan was then decided upon. A manifold book of 200 pages was designed with the original sheet perforated. This sheet was to be delivered to the assessors for their work, the copy to remain in book form on record in the Engineer's Department.

The work at the Registry of Deeds is done by one of the young men of the engineer's office, and as a book is filled and returned, the original sheets are removed, the necessary changes made on both maps and tracings and the sheets turned over to the assessors.

Before the end of the first year under the new régime, it was found that the assessors' records were not only incomplete, but very badly mixed, and it was decided to arrange a street index of the entire city. Cards were designed, a system arranged, and work on the index started in the spring of 1898. As this index was to be used for the levying of all municipal assessments, each lot had its own card so arranged as to contain all necessary data, as number of map sheet, all possible street numbers, areas, frontage of lot and date, book and page of record. These cards are kept up to date and are of very great assistance to nearly all departments. Work on this index, at the beginning, was very slow for many reasons. It was entirely new in every detail, it was impossible to take the data of the assessors and follow them regularly, most of it had to be dug out, and during the first two years only about five months' actual time was put in on this work. As the number of completed streets increased, the assessors realized the assistance it was to be to them, and plans were formulated for a card system for their entire work. After considerable time and study, in 1905 cards were designed and a system arranged for the Assessors' Department, so that now these transfers are received in the Engineer's Department, the plans and tracings corrected, the changes made in the street index and the transfers sent to the assessors, where the necessary changes are made on the street and ledger cards.

The question may be asked: What if one of these transfer records is lost? If that record arrives in the engineer's office it must show up somewhere.

In the first year of the adoption of this system nineteen errors in assessment were detected in the Assessors' Department, and this out of 10 076 accounts, each account averaging between six and seven items, and last year only three re-assessments were made necessary.

The number of transfers recorded varies greatly with the different years, 1 025 the smallest and 2 285 the largest, while

the total number taken for the past ten years is 15 800, or an average per year of 1 580.

The transfer, as originally taken by the young man at the Registry, contains the nature of the document, date of acknowledgment, date of record, book and page, grantor, grantee and location of property, and, if contained in the instrument, the area, frontage, lot number and reference to plan. About 10 per cent. of these records have to have the entire description copied, as it is the only way the lot can be located. About 50 per cent. of these transfers have either area or frontage or both missing. The time occupied by the young man at the Registry varies from sixty-three to seventy-eight days, but this includes any time that he may spend in copying plans that have been recorded during the year.

It is also necessary to obtain from the Probate Court the disposition of real estate by will, and the heirs of deceased persons holding real estate who died intestate. The time required to obtain these records is about ten days and the number of records varies from 63 to 285. These records are not copied in duplicate, but all information necessary for the Assessors' Department is copied and given directly to them.

With the exception of that portion of Lowell annexed from the town of Tewksbury in April, 1906, the street index is completed and up-to-date and we have within the next two months to complete this portion.

This street index is now used for real estate, street watering, sewer, sidewalk and moth assessments, and has contributed largely in reducing the number of illegal tax sales by the city treasurer.

[NOTE. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by October 1, 1909, for publication in a subsequent number of the JOURNAL.]

WILLIAM EIMBECK: A MEMORIAL.

By William H. Bryan, Member of the Engineers' Club of St. Louis.

[To be presented to the Club September 15, 1909.]

Among the charter members of the Engineers' Club of St. Louis who took part in its organization in the spring of 1869 was William Eimbeck, whose unexpected death in Washington, D. C., on March 27, 1909, was a shock to his many friends. He was buried April 1, 1909, at New Haven, Mo., where members of his family still reside.

William C. J. Eimbeck was the third son of the late Fried. Eimbeck, inspector of the Government Museum and Pheasantries at Brunswick, Germany. William was born in that city, January 29, 1840. He was largely self-educated, but also attended public and private schools, and later the Polytechnic and Agricultural College, under Prof. Dr. Roeleke, where he made phenomenal progress, particularly in mathematics. He came to the United States in 1857, landing in New Orleans and proceeding to St. Louis, where he accepted a position as draftsman with Palm & Roberson, builders of locomotives, then located at Third and Lombard streets. This company built many locomotives for the old North Missouri Railroad, now the Wabash. In 1860 he became assistant and deputy to Wm. J. Cozens, county surveyor of St. Louis County, and was later assistant to county engineers Gen. Charles E. Solomon and August Elbing. For these nine years his principal work was as civil engineer in municipal and county offices. He also did some work in connection with the Eads Bridge and the St. Louis water works, then actively under construction. He was tendered the offices of county and city engineer but declined in favor of men of family, he himself being and remaining all his life a bachelor. About 1868 he also became connected with Washington University, serving as its first professor of engineering and practical astronomy.

In 1870 he was sent by the United States Coast and Geodetic Survey to Sicily to observe the total eclipse of the sun, December 22, 1870. Missing the United States steamer at Naples, he was invited by Professors Lockyer and Darwin, Jr., of the British astronomical party, to accompany them on the steamship *Psyche*, en route to Catania, Sicily, to observe the same eclipse. Ten miles east of Catania the *Psyche* struck a rock and sank, and Mr.

Eimbeck reached Catania in a life-preserving boat, saving only his instruments and his Star Spangled Banner.

His most important work was in the United States Coast and Geodetic Survey, which service he entered permanently in 1871. This work is graphically depicted in the following passage from a letter from Mr. O. H. Tittmann, superintendent United States Coast and Geodetic Survey.

"His connection with the Service dates from 1869, when as a volunteer observer he observed the details of the solar eclipse of August 7 of that year. The Coast Survey had arranged for a chain of parties in the middle west to observe this phenomenon, who coöperated under the personal direction of Prof. J. E. Hilgard, then assistant in charge of the Coast Survey, and later superintendent of the same. Mr. Eimbeck was in one of the parties organized by Mr. Julius Pitzman, the county surveyor of St. Louis County, and was stationed at a point in the vicinity of Mitchell, Ill., and later assisted in the determination of the latitude and telegraphic longitude of St. Louis, and the connection with this astronomical base of the various eclipse stations in Missouri and Illinois. It is notable that this was the first exact determination of the longitude of St. Louis. The relations thus inaugurated led to his being selected as a member of the expedition which Prof. Benjamin Peirce, superintendent of the Coast Survey, took to southern Europe for observing the total eclipse of the sun which took place on December 22, 1870, Mr. Eimbeck being assigned to the party under the distinguished astronomer, Prof. C. H. F. Peters, with whom he made the necessary observations on Mt. Rossi, near Catania in Sicily. The ability and acquirements which were demonstrated in these two astronomical undertakings induced the superintendent to recommend to the Secretary of the Treasury an appointment in the Survey as subassistant for Mr. Eimbeck, and on June 5, 1871, this recommendation was approved, and the actual appointment was made on July 1. His first assignment was to one of the triangulation parties on the survey along the 39th parallel of latitude which was operating in Missouri, extending the work westward from the base in the Great American Bottom opposite St. Louis; and later he was engaged in astronomical duties in connection with determination of latitudes, longitudes and azimuths in Kansas, Texas and Louisiana.

"In 1872 he was ordered to the Pacific coast, and for the following five years was engaged in astronomical and primary triangulation work along the coast from Oregon to the entrance of the Gulf of California, one of his undertakings being a determination of the geographic coördinates and magnetic elements at thirteen stations between San Diego and Cape San Lucas for the control of the survey of the coast of Lower California, then in process of execution by the Navy Department. In 1872, in the superintendent's report, is an evidence of the thorough spirit in

which he entered upon securing a thorough command of all the details of the scientific operations upon which he was engaged, this being shown by his paper suggesting improvements in the Hipp chronograph, then used in connection with the telegraphic longitude operations.

"In 1877 he returned to the Eastern coast, where he was instructed to take up an extensive astronomical and magnetic campaign for the determination of latitudes, longitudes and the magnetic elements in Kentucky, Illinois, Tennessee, South Carolina and Georgia, and later, after making the necessary preparations, in 1878, was ordered to return to the Western coast and begin at Pah Rah, in Nevada, the extension of the primary work eastward from the coast triangulation, which was to follow approximately the 39th parallel of latitude to the capes of Delaware. This was the inception of what was to be main life work of Mr. Eimbeck and to which, for eighteen years, he gave all that was best in both mind and body. Stretching from the Sierra Nevadas to Pike's Peak in the east line of the Rocky Mountains, and including in its list of occupied stations mountain peaks reaching an elevation of 14 400 ft., in regions where supplies had to be carried for hundreds of miles through deserts and wastes, destitute of roads, and almost destitute even of water, the successful conduct of this work called for the endurance of the most rugged of pioneers and the undaunted courage of the explorer, while the operations represent the highest type of work demanded from the scientist and observer. In this triangulation one line, observed in both directions, is over 183 miles long and not exceeded in the work of any country; and another example which attests the giant character of the work is a spherical excess in one triangle of over two minutes.

"There are two instances where the change between adjoining stations necessitated a journey of 300 miles, one of these during the transfer of parties from Mount Ellen to Mount Tavaputs, made under the fierce suns of August and September, across a desert section which tested almost to their limits of endurance the men and animals, and it is remarkable to relate that in his most expansive moments Eimbeck never seemed to consider that any special merit could be claimed for successfully overcoming all these hardships and dangers. A reference to the annual report of the superintendent will emphasize this feature of our friend's character, as therein will be found only a simple statement of the work completed each year, because of the modesty which would not permit him to give an adequate account of the toils he faced and conquered. Coast and Geodetic Survey Special Publication No. 4 gives the details of the scientific feature of Eimbeck's great share in the measurement of the arc of the 39th parallel. His report on the Duplex Base Apparatus designed by him for the Coast and Geodetic Survey, and the report of his measurement of the Salt Lake Base with the same apparatus, are the two principal published reports prepared by Mr. Eimbeck."

Mr. Eimbeck's invention of the Duplex Base Apparatus, his design of an Invariable Reversible Pendulum, the improvement

of the Hipp chronograph, and his work in connection with the observation of eclipses, both in this country and abroad, were accomplishments which attracted the attention of scientists the world over. His survey from the Atlantic to the Pacific on the 39th parallel of latitude, which occupied nineteen years, was really his life work.

Ill-health and a desire to devote his time more closely to scientific research led to his resignation from the Survey in 1906.

He was a frequent contributor of scientific articles to magazines and journals, many of which were translated and published abroad. He was a founder of the Cosmos Club of Washington; a member of the Washington Academy of Science, the National Geographic Society, the Geological Society, and the Washington Philosophical Society, and for thirty years a Fellow of the American Association for the Advancement of Science.

He was a man of pleasing personality, but of such modest demeanor that few knew of his accomplishments and attainments. An interesting appreciation of Mr. Eimbeck's work and personality is the memorial address delivered May 22, 1909, before the Philosophical Society of Washington, by Mr. Edwin Smith, of the Coast and Geodetic Survey, published in *Science* of July 9, 1909.

WILLIAM EIMBECK.

(See Memoir, page 36, July JOURNAL)

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HEAT: ITS USE AND DISTRIBUTION.

BY LYMAN C. REED, MEMBER LOUISIANA ENGINEERING SOCIETY.

[Read before the Society, May 10, 1909.]

SINCE the subject presented to-night has been of absorbing interest to physicists for many years, I approach it, and desire to present it to you, from the standpoint of a student and not an instructor. Many volumes have been written on what must here be briefly sketched, and the endeavor will be to transform our appreciation of heat phenomena into an active instead of passive acceptance.

To the average layman the problems connected with our use of heat appear detached and isolated. He fails to grasp the correlation of the various manifestations of heat phenomena. Ordinarily the word "heat" is used to denote an appreciable rise in temperature above that which our bodily senses label as normal; but the word has a much broader meaning, and the farther the investigation proceeds the more we find that forces set in motion by heat transference are integral with life itself.

The philosophy of heat is the study of its transference from one body to another, and without transference heat is useless as a work agent. All mechanical effort of whatever nature can be expressed in its equivalent heat value, and vice versa. Therefore, in considering heat phenomena, we must study its manifestations if we desire to arrive at a true appreciation of its relation to our present civilization. In dealing with the various forms of heat and its transference, no attempt will be made to more

than outline their general relationship to each other and to the source of all heat.

Heat is transmitted by radiation, conduction and convection. Radiant heat is transmitted by the ether which permeates all matter and stellar space. Heat by conduction is transmitted by molecular activity along the same substance or from substance to substance in contact. The transference or shifting of heat by convection is only possible in liquids or gases where masses of heated material are shifted bodily into contact with other masses, the final heat transference taking place either by radiation or conduction.

The earth receives heat from many sources, but its chief supply comes in the form of radiant heat from the sun. The active principle which makes the sun the supplier of heat for our planetary system is purely a matter of conjecture, but the most recent discoveries in atomic activity would seem to point to the transformation of the sub-atomic kinetic energy into heat as the maintainer of the sun's heat. That radiant heat is purely a force carried by the ether, and not an atomic or molecular transmission, is evidenced by the extreme cold on high mountains. The heating of the atmosphere and earth is accomplished by the force in the impinging ether waves being transformed into molecular activity which becomes sensible as heat. The ether may therefore be considered as an elastic medium through which the molecular activity of the sun is conveyed to the earth, the intervening space being in a state of absolute cold. By means of the hydrogen thermometer the absolute zero, or state of matter or gas where all heat is absent, has been determined as 273 degrees cent. (below freezing point). At this temperature all molecular motion of matter ceases, and it is presumed that this is the temperature existing in stellar space.

The atmosphere which envelopes the earth furnishes a medium that enables us to exist, and its temperature varies in different zones and seasons, this condition being brought about by the changing relations in position of the earth and sun. Minor local disturbances are set up by air and ocean currents caused by varying heat conditions, but the atmosphere as a whole acts as an equalizing agent, and all objects enveloped therein tend to become of the same temperature. A piece of ice placed in a bowl and exposed to the air becomes of the same temperature in time, as likewise does the red hot iron removed from the fire. The ice can only remain ice when the air is warmer than it is by an expenditure of energy, and the iron can remain hot by the

same means. The surrounding air is temporarily cooled by the melting ice and likewise heated by the iron, but the cooling and heating are equalized and blended until the melted ice, iron and air reach the same temperature. The quickness of this blending is dependent upon the value of the heat insulation separating the objects. Where the objects differ greatly in heat potential the instant blending of their heat values results in many cases in violent disturbances similar to the disturbance caused by the short circuiting of electric currents of high potential. It is much more difficult to insulate for heat than for electricity as nearly all solids and liquids are fairly good conductors of heat, while many substances are practically perfect insulators for electricity.

If a pound of iron at 400 degrees fahr. be immersed in a pound of water at 100 degrees fahr. the resulting temperature of the water and iron will be about 124 degrees, neglecting the loss from radiation. This resultant temperature will be rapidly reduced to that of the surrounding atmosphere. Now if the pound of iron instead be placed on a table a foot away from the vessel containing the pound of water the iron and water will be reduced to atmospheric temperature without the iron having appreciably raised the temperature of the water.

From the above is deduced the law that bodies of differing heat potentials are equalized in temperature along the lines of least resistance.

The mere fact that the earth and atmosphere are such large quantities in comparison with other objects makes their temperature the controlling factor in all heat equalization.

As heat is recognized as molecular vibration, it is apparent that all objects in a state of heat equilibrium vibrate in synchronism, and when this vibration is accelerated or diminished by a change of state or condition the temperature is said to increase or decrease as the case may be. A change in temperature can be produced by the direct application of heat or by various other equivalent means, but in order to keep the object from synchronizing with its environment the application must be maintained. The work thus performed or energy equivalent may be expressed in concrete form and has been defined as the mechanical equivalent of heat. The amount of work represented by raising the temperature of one pound of water from 60 to 61 degrees fahr. is equivalent to the force necessary to lift 778 lb. through 1 ft. It is evident, therefore, that the momentary energy equivalent to any object raised above or depressed below the

temperature of its environment is expressed as 778 ft. lb. multiplied by the number of B.t.u. contained in the object. This energy may not be in shape to use commercially, and frequently merely represents the transference of heat from one body to another. All heat values are in a constant state of mutation, and it is fair to assume that the heat received by the earth from the sun during one complete orbit just balances that which the earth radiates during the same period, otherwise we should either roast or freeze in a short time. Thus all matter, including the earth and atmosphere, when raised above the temperature of its surroundings, tends to return to the absolute zero but is arrested in its progress by encountering a temperature maintained by the sun's influence.

The quantity of heat in any earthly object is so infinitesimal in comparison with the sea of heat in which it is immersed that it is only a question of time until a like temperature is reached. In the same manner any matter which has been carried below the temperature of its environment either by artificial or natural means cannot descend lower without the expenditure of energy, but is restored to the temperature of its surroundings by transference of heat to it from surrounding bodies.

A simple explanation of these phenomena of heat transference is furnished by the theory that all matter radiates heat, the object of low heat potential having its molecular vibration accelerated by the surrounding objects of higher heat potential, the whole earth being kept in a state of heat activity by the ether waves received from the sun. It is worthy of notice that all heat transference takes place from the warmer to the colder body.

Does not the question here arise whether the mean temperature of the earth is a rough measure of the power of the ether waves impinging thereon? The fact that any substance exposed to the hottest rays of the sun does not rise above 200 degrees fahr. shows that the sun's rays unaided cannot excite a greater molecular activity than that of which this temperature is the index. Greater temperature can be obtained by focusing the rays through a reflector or lens; the momentum of the impinging ether waves is not changed nor their intensity, but they are simply added together.

A simple analogy would be furnished by dropping a flat disk of large diameter and a rod of the same weight from a given height. The impact would be the same, but the penetration of the rod would be far greater than that of the disk.

The difficulty in focusing a quantity of the ether waves to

raise a large mass to higher heat potential has been the stumbling block in our utilization of the sun's rays for power purposes. Another analogy is presented in our large rivers of low head; the quantity is there, but the potential or head renders their use of little value.

Before passing to a consideration of the use of heat, a few of its most salient properties will be noted.

Radiant heat, light and electricity are transmitted by ether waves of different lengths and frequencies traveling at the rate of 186 000 miles per second. Radiant heat waves impinging against a mass are transformed into molecular activity in proportion to the mass's thermal conductivity.

Light waves impinging against a mass are either transmitted, reflected or absorbed, according to the nature of the substance.

When electricity is transmitted over a conductor it travels with the speed of light but sets up in the conductor a molecular activity proportional to its conductivity which manifests itself as heat. Such metals as silver, copper, mercury, iron, etc., exhibit approximately the same thermal and electrical conductivity, showing that the molecular resistance to heat and electrical transference is in the same ratio.

It takes an appreciable time to heat a conductor either by electrical or thermal means, but a conductor of uniform cross section and given length is equally heated in all parts at the same time by the passage of electric current but very slowly and in diminishing degree from the heated to the colder portion by conductive heat. A molecular mass is, therefore, necessary to conduct electric current of low periodicity such as we use commercially, but offers a screen to radiant heat varying in effectiveness with the nature of the substance. Can we not consider the heat manifested in an electrical conductor as a sort of molecular friction caused by the ether waves in passage, particularly in view of the fact that the heat generated is directly proportional to the cross section of the conductor?

The recent developments in radio-activity and the marvelous heat-giving qualities of radium have changed the theory of atomic activity into one endowing the atoms with active particles called electrons which contain an electric charge. These electrons are about 1–1 000 the size of the hydrogen atom and are supposed to revolve in groups forming atoms. The emanations from radium seem to consist of these highly charged electrons, and 1 gm. of radium in disintegrating gives out as much heat as the combustion of a ton of coal.

Heat in the abstract is, therefore, more possibly activity of the electrons than molecules themselves, and the intensity of this activity defines the amount of heat. A blow, a radiant heat wave, a convection current of heated air and the thing we call substance responds at once to the greater activity, in turn passing it along to some other substance, all by means of an elastic medium which permeates all things, yet is unseen, unfelt, untasted, — the ether.

A great similarity exists between the laws of heat and the laws of gravity. Bodies at rest remain at rest unless energy is exerted to move or set them in motion, and the same rule applies to a change in temperature. The energy needed to disturb a body can be expressed in both instances in heat equivalent.

The law of gravity may be expressed in B.t.u. value of the stored potential and kinetic energy imparted to a body in motion. Thus 1 lb. of iron raised 1 ft. from the ground in one minute represents when released a B.t.u. value of .077 units. Bodies at any temperature above absolute zero require the expenditure of energy to keep them stable and this may be imparted by the surrounding objects; their net loss equals the object's net gain. Any change in equilibrium either through the law of gravity or heat transference causes an object to give out a heat or mechanical value.

The absolute zero which all matter reaches when heat is absent may be used as a base from which to calculate heat potential, as the center of the earth is used as a base in gravity calculations. The temperature of any body on the absolute scale is momentarily its index of heat stress or potential. To illustrate: A pound of water at 60 degrees fahr. would equal 519 degrees on the absolute scale, and its work equivalent above absolute zero is 519 multiplied by 778 ft. lb. A pound of iron at the same temperature would have the same work value divided by the ratio of its specific heat to that of water, which is about 9. In like manner, any mass's absolute work equivalent may be determined. Between two objects of the same temperature, no heat passes; therefore, no work is done. It is only by raising the heat of one above the other than work may be done. All commercial work, therefore, resolves itself into the transference of heat from a high potential to a low potential body.

In passing to the discussion of the use of heat, we have seen that all energy in its final analysis is the work done in the equalization of temperature between different bodies, and it is necessary in order to use it commercially to have this equalization take place in such manner that it can be readily utilized.

The evaporation of water by the sun's rays, and its subsequent precipitation in the form of rain or snow, which, in turn, is stored in the earth and gradually conveyed by rivers to the ocean, constitutes an energy cycle which continues ceaselessly. The portion of this cycle which deposits rain or snow renders possible the growth of vegetation which through long processes of the ages has been transformed into coal, natural gas, oil, etc. All of these substances possess given heat values which, through certain well-known processes, man converts into available heat of higher potential.

The vegetation nourished by rainfall helps the rain to filter into the soil and be given out gradually in springs and rivers. The unevaporated portion of this water finally reaches the sea, where it is again evaporated and put through the same cycle. The process of evaporation, being a continuous one, has piled up enormous quantities of stored heat equivalent in the form of coal, oil, gas and forests, all of which may be considered as by-products of the great evaporation cycle in which our water powers are by far the largest exponents. The amount of the sun's energy thus stored is estimated as only about 1-1 000 of that delivered to the earth.

The fact that the earth is not at all points of an even surface causes the water that is deposited to seek the point nearest the center of the earth, acting in this way as an agent of the law of gravity. Water in traveling from a higher elevation to a lower can be made to give up a heat equivalent or work value proportional to its mass and fall. The total aggregate of such power reaches many million horse-power and is continuously available. The non-utilization of this heat equivalent is a great economic waste which we have scarcely begun to remedy.

Coal, oil and gas have been heavily drawn upon for fuel purposes, and the supply is rapidly diminishing without a chance of their being renewed. The forests have also been greatly depleted for fuel and other purposes, and unless the destruction ceases our water powers will be greatly impaired and their availability for fuel or heat correspondingly injured. The artificial storage of the direct heat of the sun has not been satisfactorily accomplished, and until this problem is solved we must depend on water power and other means before mentioned to furnish our commercial heat and energy.

The animal kingdom outside of man has no knowledge of the use of fire or other forms of heat, and this knowledge is one of the greatest factors in marking the barrier between certain animal

species and the lower orders of man. In other words, our expertness in the use of fire or other forms of heat is in a great degree the measure of our advancement in the animal kingdom. In our daily lives, artificial heat in some form or its mechanical equivalent is at the foundation of nearly all our conveniences and activities. The ancient Greeks made the snatching of fire from the gods the distinguishing event in the development of man, realizing that without heat in its various forms we should not have risen above the level of the beasts. The words, " heat, energy and power," are used synonymously in this discussion as they are interchangeable terms.

The heat demands of our present civilization are so enormous that we can already look forward to the time when the stores of coal, oil, gas, etc., will be so depleted that other methods of deriving artificial heat or energy must be found. No doubt the pressure of necessity will solve the problems as they are presented.

The value as a heat producer of any of the present agents at our command is measured by its B.t.u. value. In deriving heat or energy from original storage elements the mechanical equivalent of heat is the end usually sought, but the cycle is never complete until this mechanical equivalent has been again resolved into its primary state — heat. The use of any particular storage unit from which to obtain its equivalent in direct heat or mechanical equivalent is generally determined by its cost and availability. A further modification is introduced by the sub-agent employed in distributing the heat units or energy made available. It is the purpose of this treatise to define broadly, the best methods of economically using and distributing the various heat storage elements placed at our command.

The principal sub-agents employed in direct and indirect heat applications are air, water, steam, gas and electricity. These sub-agents are the conveyors of high potential heat to places where the heat equalization or work equivalent is used.

Direct heat applications may be considered to embrace the heating of buildings, furnaces, cooking utensils, etc., while indirect heating includes these and the various mechanical and chemical equivalents used in commercial life.

The development and utilization of water power as a means of performing useful work dates back many hundreds of years, but the development was insignificant until the discovery of a suitable distributing agent. Broadly speaking, the heat units represented by the energy of a water power are constant, and the

final dissipation into various forms of mechanical equivalents are misleading only in so far as we fail to realize the final values of the transformation.

Early users of water powers were confined to running small mills principally for grinding grain and sawing lumber. Later, mills and factories located on the banks of streams where water power was available obtained their power through water wheels and, through the agency of shafting and belting, were made to perform mechanical work on a large scale. It was not until the advent of electricity as a distributing agent that water power could be used economically at a distance from its site, either as a direct heating agent or in some form of mechanical equivalent.

In transforming the energy of a water power into electric power a certain percentage of the original power is not transformed in the manner desired but is given off in heat in various ways. The friction of the water in the penstock and wheel, the friction of the bearings supporting the wheel, and the various losses in the generator itself, all manifest themselves in the form of heat which is given off to the surrounding objects and dissipated.

The conversion of the electricity generated into mechanical or heating and lighting effort shows another loss varying with the degree of efficiency of the translating units. The total amount of heat equivalent generated is finally diffused and equalized at atmospheric or surrounding temperature or stored in some latent form for further transformation. The process of analyzing the complex quantities involved in each transformation is beyond the intent of this discussion, but it is desirable to keep in view the conception of heat equalization as broadly outlined. The economy of heat distribution by means of various sub-agents ranks among the absorbing economies of our race and is kaleidoscopic in viewpoint.

Nature's most generous gift to man is water power, and its preservation and utilization are among our chief concerns. In order to preserve the water power, the forest must be preserved, which in turn contributes to our coal supply. Thus we see that the great original energy storage agents are so interlinked as to be inseparable; their intelligent use must appeal to us as a duty.

In utilizing the water power as a distributer of heat it is found that electricity offers the most efficient sub-agent. As much as 70 to 75 per cent. of the energy of the water power is thus made available for a distribution whose efficient radius is being constantly enlarged. The development of long-distance

transmission has been rapid, and systems are now in use where the power is used four to five hundred miles from the site of the water power.

In order to make this transmission of power a success a market must be found or one created for the sale of applied heat in its various forms. Among the largest users of applied heat is the city, as the number of heat units used per capita is much larger than in rural districts. The demand for light, transportation, heating and factory operation represents a greater unit activity in cities than in rural districts and, in fact, the capital investment is so great to reach a widely scattered rural district that it seldom pays to distribute heat units from a central source. This condition is modified where a central supply system traverses a rural territory to reach a market further on. Latent storage agents such as coal, wood and oil are used to furnish individual heating needs both in city and country where the cost of obtaining heat units from a central supply system is prohibitive. This statement is misleading on analysis because in any instances the additional load of this class of heat users would make a central distributing system commercially profitable by reducing the fixed cost per unit.

While the energies of water powers are almost universally distributed by means of electricity, some of them, as has already been cited, are transformed directly into mechanical effort. The final dissipation of this mechanical energy manifests itself in the form of heat or its latent equivalent. Even where extended distributing systems are not contemplated, it is frequently found that power distribution is more cheaply accomplished by electrical than mechanical means. This applies especially to large factories and industrial plants scattered over large areas. In plants where the absorption of energy is purely mechanical, its entire equivalent is dissipated in heat, but in many instances a certain proportion of the energy is stored in the form of latent energy. In the manufacture of calcium carbide and other chemicals a portion of the energy used in their production is stored and held in suspense until released at man's option. The generation of acetylene gas from calcium carbide and water makes a gas that is suitable as a direct heating agent and when ignited completes the cycle started at the water power. The storage battery may be taken as another example of latent heat or energy accumulator where the final dissipation of the original heat value of the current stored is held in suspense until the battery is discharged and the current reconverted into direct heat or its mechanical equivalent.

In transforming a water power into electricity only a portion of the available power is liberated in heat at the time of transformation, but in the transformation of wood, coal, gas or oil into electricity, the present process is to liberate the entire available heat units by combustion and then absorb as many of them as possible in some sub-agent for distribution. This process takes place in our present boilers where the water is used as a link in the cycle of transformation. The average loss in this first transition between the heat released by combustion and that absorbed by the water in the boiler is about 40 per cent. of the original heat value of the fuel. This 40 per cent. is spoken of as lost because it is not available for useful work. The remaining available 60 per cent. may be distributed for primary heating purposes either as hot water or steam. The convection principle is employed in the use of hot water or steam as heat distributors, but the local application in heating large buildings or groups of buildings is accomplished by radiation and convection. Cooking and washing are also among uses these sub-agents fill, but are seldom available from a central distributing system. Owing to their limited availability hot water and steam are not widely used as heat distributors for other than primary uses, such as direct heating and driving steam engines.

It has been shown previously that the efficiency of a water power was as high as 75 per cent., and it has just been shown that the efficiency of an ordinary boiler is about 60 per cent., demonstrating that for direct heating purposes the water power is the most efficient, but owing to cost of development may not be the best to use commercially.

Steam may be styled a low potential and electricity a high potential heat distributor, the low potential being best suited for short distances and the high potential for long distances. Low potential distribution by steam fulfills so few needs that we are compelled to transform it into high potential heat equivalent, — electricity. The loss between the heat value of the coal and its final equivalent in electricity averages about 90 per cent. This wasting of our natural resources is only condoned by our ignorance; we have not been able to do any better. A comparison with water-power efficiency shows how much better we have mastered mechanical properties of primal heat transference.

Other forms of sub-agents for heat distribution are in extended use and gas may be considered the chief form from a standpoint of direct heating value. A pound of coal of 14 000 B.t.u. heat value transformed into gas would give an average of

5 cu. ft. of gas of a total thermal value of 3 000 B.t.u., — not much better than 20 per cent. efficiency. The by-product coke, tar and other ingredients of coal all have a heat value which makes the apparent result less wasteful. Gas admits of much more extended distribution than steam, and in many instances, particularly with natural gas, is transported hundred of miles economically. In view of the variable heat values of the residue left from a pound of coal converted into gas it is very hard to consider gas alone as a sub-agent of heat distribution by assigning it a definite efficiency of transformation. This phase of the problem had best be taken up under a later head wherein the commercial efficiencies of the various sub-agents will be determined.

Natural gas and crude oil are among nature's primal heat storage agents and form a group secondary in importance only to the three principal agents considered. Natural gas is almost universally applied directly as a heating agent and is transformed through gas engines into a mechanical equivalent for the performance of useful work. These gas engines may in turn drive electric generators. The efficiency of transformation of natural gas into electricity is much less than water power into electricity. The thermodynamic efficiency of a gas engine may be as great as 25 per cent. and the electric generator 97 per cent., making a combined efficiency of 24 per cent., as against 70 per cent. obtained from a water power. Natural gas is directly comparable to a water power, and where conversion to electricity must be performed for distribution it should never be burned under a boiler where the final result in the form of electricity would average not better than 10 per cent. of the original thermal value of the gas. The same argument applies to crude oil, and it should be considered a criminal waste of natural resources to burn oil or gas under a boiler for further transference into mechanical or electrical power.

Having briefly outlined the relation of the various primal heat storage elements and their use, it is in order to tabulate them so as to fix them in their permanent relation.

Water-power conversion to electrical or mechanical equivalent 70 per cent. efficiency.

Coal, wood, gas or oil under boiler to hot water or steam equivalent 60 per cent. efficiency.

Coal, wood, gas or oil under boiler for mechanical or electrical equivalent 10 per cent. efficiency.

Coal or oil into producer gas 20 per cent. efficiency plus coke, tar, etc., as by-products.

Natural gas, manufactured gas, crude oil, converted in gas or oil engine 25 per cent. efficiency of the fuel value.

The same converted into electricity, 24 per cent. efficiency.

From the above it is seen that of all the primal heat storage agents, water power at present furnishes the one we can use most efficiently. This use, however, may entail a greater cost of development and utilization than some cheaper transformation from other elements. This would probably be the case in the presence of a large pocket of natural gas or oil which for a brief period would furnish heat at a minimum cost. But all such sources of heat are exhaustible; our supply of coal, oil and gas is so well defined that it is merely a matter of calculation as to the number of years they will last at the ever-increasing yearly rate of consumption. The great continuous sources of energy that are constantly renewing themselves are the water powers and the forests. As long as the sun shines on the earth the cycle of evaporation, condensation and precipitation will take place and produce our rivers from which we derive our water powers. The forests act as the equalizers or governors of the run-off, so that we have a somewhat average flow throughout the year. The excess forestation or growth may be utilized for lumber, fuel, and the thousand and one purposes to which it is put. If these forests are destroyed the greatest agent we have for the use of primal heat is taken away, and it would only remain to exhaust the already depleted coal, gas and oil fields to destroy our present industries and civilization. This feature is dwelt upon because it becomes imperative for us to solve the problem of the most economical use of our primal storage agents in order to conserve them as long as possible. This brings us to the general deduction that all forms of direct or indirect heat application should be carried out by the agents or sub-agents offering the most economical use of the original primal agent. We must capitalize the primal heat agency, giving the B.t.u. a primal value from which all derived values must be taken. Thus a water power may be expressed in equivalent B.t.u. value, a pound of coal, a gallon of oil, or a cubic foot of natural gas or a cord of wood. That a basic cost per B.t.u. is proper may be proved by reducing the interest charge on the cost of development of a primal agent to its equivalent B.t.u. value. In other words, all energy, whether represented by human labor, stone dams or turbine engines, has an equivalent B.t.u. value. Thus we say that the cost of delivering a horse-power of electrical energy per year from a given water power is $10. This $10 represents fixed charges,

depreciation, operating expense and a reasonable profit on the investment without any value being placed on the water itself outside of the cost of the original water rights. Reducing a horse-power year to its equivalent B.t.u. value, we find that the cost is 0.000045 cents per B.t.u., or 4½ mills per 10 kilo-B.t.u.'s, of derived energy. This represents the basic B.t.u. cost of this particular water power in the form of electrical energy. The additional costs of transmission and transformation are not included in the above.

Coal at the mine may be compared to a water power. The cost of coal delivery at the mine mouth should include the cost of mining, interest on the investment, sinking fund and a reasonable profit. Assuming this value at a dollar per ton, and an equivalent B.t.u. value of 14 000 units per pound of coal, a value of 3.6 mills per 100 kilo-B.t.u.'s is found to be the basic value in direct heat units. As has been pointed out, this heat value transformed through steam into electrical energy would give a cost of 3.6 mills per 10 kilo-B.t.u.'s without any addition for fixed charges on plant equipment, which formed the greater portion of the cost in the water-power estimate. Assuming the cost of $75 per horse-power for plant equipment, and calculating interest and depreciation at 10 per cent., operating costs at $3.50 per year, we should have a charge of 4.5 mills per 10 kilo-B.t.u.'s, making the total cost per 10 kilo-B.t.u.'s, 8.1 mills. This proves that under the most favorable conditions coal cannot be burned under a boiler, transformed into electricity and made to compete with water power at $10 per horse-power per year, but is equivalent to a water power at $17.50 per year. The same coal used in a producer gas generator and the gas utilized in a combustion engine will give far greater economy in the use of fuel, but owing to the greater cost of the plant the final economy is not very much better.

With coal at $3.00 per ton the comparison is greatly in favor of the producer gas plant, as the fixed charges and operating remain the same, the values being 15.3 mills for steam and 11.4 mills for producer gas per 10 kilo-B.t.u.'s. As a rule, all gas engine plants are more expensive than the equivalent steam plant, varying from one and a half to two and a half times the cost of the steam plant. If the same interest and depreciation are charged on both equipments and the operating cost worked out, it is an easy matter to determine from the fuel cost which type of plant is best for a local condition.

If direct low potential heating is required it can be

generated, including the boiler cost, at less than one mill per 10 kilo-B.t.u.'s, which is practically 22 per cent. of the cost of high potential heat distributed from a $10 per year horse-power water power. Many low-head water powers that will cost huge amounts of money to develop will remain in their present state as long as the cost of other forms of stored energy can be applied more cheaply. The cost of coal, oil, natural gas is certain to increase as the quantities become more limited, especially if the problem of storing and using the direct heat of the sun remains unsolved for commercial application. In time this will force the development of every possible water power, and the intrinsic value of the water power will be further modified by the character of the market to which it must look for support.

The comparison between coal and water power in the foregoing was based on the cost of coal at the mine, but if coal be figured at $3 or $4 per ton, as it must be for some sections of our country, the comparison becomes still more unfavorable. Equalizing factors may exist in the market being a great distance from the water power, in which event the interest and depreciation on a transmission line would possibly offset the greater cost of coal. Determinations such as these must be made for each local condition. The easiest way to solve the problem for any locality is to ascertain the intrinsic value of a kilo-B.t.u. of the nearest water power and compare this with a like value for coal, natural gas or oil at the nearest point of delivery, adding to each value the cost of delivery per kilo-B.t.u. at its market. Assuming a cost of $\frac{1}{4}$ cent per ton mile for transporting coal and a haul of 400 miles, we find that it would cost $8 650 to deliver 1 ton per hour each day of the year. This is equivalent to an average of 1 000 e.h.p. per hour if generated in a steam plant. The transmission of a 1 000 h.p. 400 miles, assuming the cost of the line to be $4 000 per mile, and interest and depreciation at 10 per cent., and line loss at 10 per cent., would be $161 000 per year, showing that it is much cheaper to transmit the raw material than its equivalent in electrical energy. The above will apply to gas and crude oil in even greater degree. If, instead of transmitting 1 000 h.p. per hour electrically, we transmitted 20 000 h.p., the cost for interest and depreciation on the line would remain practically the same, but the cost per 1 000 h.p. would be $8 050 as against $161 000; 10 000 h.p. would cost $16 100 per 1 000 h.p. This shows that a balancing ratio exists between the cost of transmitting raw material and generated power, and where large quantities of power are used many cities or industrial plants could

save money by removing their plants to the coal mine if water power was not available. The continuity of service is sometimes of greater value than a lower cost of production, and until long high voltage transmission systems are rendered more reliable, the steam plant will exist in localities where its economic existence should end.

In the foregoing determinations values are predicated on plants delivering large quantities of power at an average rate. A plant's load factor is very essential in determining cost, and the higher the load factor the cheaper an electrical unit can be produced. Any central distributing heat system must, therefore, try to maintain as high an average load as possible in order to keep the cost per unit of fixed charges down. It becomes incumbent on such a system to supply a community or city with a selected heat supply system so that every demand is studied and the most economical service devised to fill the need. After the basic cost per B.t.u. for any community has been determined by an exhaustive study of local conditions, the cost of furnishing each B.t.u. need of the community is the problem to be solved.

[NOTE. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by November 1, 1909, for publication in a subsequent number of the JOURNAL.]

A SPECIFICATION FOR FILING AND INDEXING RAILROAD PLANS.

By Herman K. Higgins, Member Boston Society of Civil Engineers.

[Read before the Society, January 27, 1909.]

When, some eighteen years since, the writer entered the engineering service of a certain railroad, not so large then as later, their drawings were roughly classified as land, track, bridge, building and miscellaneous plans. There was no index; plans were supposed to be put away in their proper drawers. Finding a plan was very simple: we looked in its proper drawer; if not there, in any other drawer that seemed likely to contain it. Out of regard for his reputation for veracity, the writer will not state how many men he has seen hunting for hours for some much-desired plan that had strayed from its place.

A few years later the writer was transferred from construction to office work and it became part of his duty to keep run of the plans and records pertaining to bridges. By that time the track, building and land plans had been sub-classified according to geographical location, one drawer for each division, etc. Bridge plans had also been subdivided, on the basis of Blueprints *v.* Tracings *v.* Brown paper, etc., single structures appearing in all the classes.

One of the writer's earliest innovations was the sorting out of plans pertaining to each structure without regard to quality of paper. These were then fastened together, marked with the number of the bridge and kept flat in order of such numbers, one drawer for one or more geographical divisions of the road. The bridge numbers were geographically consecutive; each branch began with number 1, and the numbers progressed as far as necessary.

The same system of numbers was recently, and, so far as the writer knows, is still in use on that line, its most undesirable feature being the necessity for interpolating whenever a new structure is established. As long as the original numerical system for interpolation is adhered to, there is little trouble, but the addition of letters combined with pre-existing fractions results in some such combination as 10$\frac{3}{4}$ E a.

The writer believes it rarely necessary to change a system of bridge numbers, and, if such system goes back well into the past, such change usually involves the loss of many valuable data,

as the old numbers are forgotten in a few years and the many references in old requisitions, letters, notes, etc., become thereby unavailable for all following seekers after data.

This self-indexing system worked very well as long as drawer room was available. In course of time the road, with several others, was absorbed into a larger system, the offices were consolidated and it became necessary to store the plans in a fire-proof vault. They had to be rolled, and the self-indexing feature had to be abandoned and an index provided.

One of the consolidating companies already had a book index, or, rather, list of plans of all kinds classified according to name of nearest passenger station. The bridge plans, the writer's work was still largely with bridges, were (on the road with book index) often found rolled up with plans of other work, cross sections, profiles, maps, masonry, earthwork, station plans, etc., all in the same roll. The system of numbering rolls was very simple. It began at 1 and had reached some 6 000 odd at the time the writer made its acquaintance. The book in which the index was kept was divided alphabetically. Each station had assigned to it a certain amount of space as its importance seemed to warrant, the stations being as far as possible alphabetically arranged. The arrangement of titles under the station names was chronological, as it was not practicable to continue and maintain the alphabetical arrangement.

In filing the plans of the other component roads it was attempted to continue and expand the above principle. A number of difficulties arose which are indirectly referred to later. Another of the component roads had a really excellent index, well classified and with all necessary data entered therein. This was largely due to its having been burned out a few years before, nearly all its records (of Engineering Department) having been burned. It had thereby a clear field and few old records to reindex; there were, therefore, only a few plans. The serious fault with the index was that it was divided by operating divisions of the road; these often change, and in this case had changed several times. Each division had a separate book, and to find a plan the seeker must either know which division it had pertained to *at the date of filing* or must look through several books.

At the time above mentioned of expanding the "station name" system of filing, the card system was introduced, largely through the writer's recommendation, the book mentioned being all copied on the cards. This formed the nucleus, a very re-

spectable one, for the present rather satisfactory index on the road in question.

There remained something yet to be desired for an index of bridge plans, and a later paragraph will show its development.

Long before the consolidation of the roads the writer had foreseen the need for a comprehensive index and had taken up somewhat thoroughly the study of indexes and self-indexing systems. There was at that time very little in print on the subject, and he was obliged to begin nearly at first principles. By the time the consolidation of the offices and consequent rearrangement demanded action in caring for bridge data, a system was well outlined and the details presented little trouble. The writer has since formulated the system in the following specification, if it may be so called. It is intentionally simple, and, so far as applied, worked perfectly for some four or five years, growing all the time. It could not be fully applied to the case in point as there was much conservatism to be overcome and little intelligent clerical assistance to be had.

The "specification" is made as full and complete as possible, the fundamental principles and the "reasons why" are given in considerable detail to the end that it may be clear and perhaps useful to readers who have indexes to make.

The writer uses the term "specification" as he intends this paper as in some sense a protest against the filing *system*, so-called, as applied to records of engineers' offices. Filing systems work well in some places; so do the characters used by stenographers; so do cipher codes. In all three there is no possible check on the one or two men who hold the key to the system. The writer wishes to express his emphatic disapproval of all cipher code filing for engineering records, and that is what much of the code filing really is. His reasons for this disapproval will be found in a later paragraph.

1. General considerations.
   Index *v.* self-indexed files.
   Notes, memoranda, etc.
   Letters and old books and papers.
   Plans.
2. Definition and scope
3. Form.
   Facility, simplicity, certainty.
   Cards *v.* book.
   Size and quality of cards.
   Arrangement: Alphabetical or otherwise.
   Number of indexes.
   Speed *v.* certainty.
   Cross indexing.
   Elimination of dead matter.
4. Plan files.
   Form and size.
   Numbering units.
   Numbers on plans.
5. Book and document files.
6. Computations, diagrams, etc.
7. Conclusion.

1. A business just starting usually requires no elaborate filing system as the person in charge of the office can remember where things are. As the business grows, data and records accumulate and more men are employed. It then becomes necessary to systematize and to keep all data where not only the chief, but also the assistants, can find them at short notice. At this point we meet an alternative: we can file in a self-indexing system, or we can file in any convenient form, and index the file.

In case the data are of suitable nature and form, the self-indexed file is usually the better and cheaper. In collecting data it is well to put them into convenient form for such files.

The writer has for years kept notes of surveys, inspections, formulas, diagrams, etc., and memoranda of all kinds, on ordinary Library Bureau cards. The larger size, about 4 by 6 in., is preferable for field notes of surveys; for most other purposes the standard size, a trifle less than 3 by 5 in., is preferable. For field use they are tied together into book form with stiff leather covers. They are filed by subjects in an ordinary cabinet of standard form and size. After cross referencing they are absolutely and permanently accessible.

For extended surveys covering many pages, and for work in which notes cannot be put on sketches but must be kept with them, an ordinary book is sometimes preferable. Moreover, such survey notes once plotted rarely need to be referred to again and the book is convenient enough; but for detached surveys, notes of inspections and, in general, all divisible work, cards (or loose leaves) have great advantages. They may be sent into the office for draftsmen's use without interruption to the outside work, and returned if necessary, or filed. On city or town survey work it is much easier and safer to carry a dozen or so cards bearing notes of former surveys of tracts adjacent to the one under survey than to carry as many old notebooks. Those of us who have done much city work, so-called, do not need to be told that old notes are likely to be of very great value in such work. If it is attempted to copy them into the current notebook, one is likely to omit the one thing most important, which omission is discovered later in the field.

Records of bench marks, reference points and the like are very conveniently kept on cards and tied into the back of the made-up notebook. The cards should preferably be kept in the office when not in actual use to attain greater safety against loss or accident.

The loose-leaf notebook which operates on the same principle,

that of divisibility, has many friends and the writer prefers it to the old-fashioned book, but he has found the cards easier to care for and more accessible when filed. This principle of divisibility is the same as that requiring letters to treat one subject only on each sheet; this principle is almost universally applied to correspondence, and its recognition in technical files will prove as profitable as it has already proved in letter files. Many other applications of this principle will suggest themselves; the main point is to plan beforehand for the filing and to get the original data in convenient and divisible form. The writer has several professional acquaintances who use this card system for field notes, memoranda, etc., and who would not abandon it on any account. Usually letters, bills, receipts, time returns, requisitions and most clerical papers can be kept in a self-indexed file, which may well be cross referenced in the general index. Some offices own as most valued possessions old plans, notebooks, etc. These are usually not susceptible of self-indexing; old plans almost never are. They must, therefore, go into an indexed file.

2. The dictionaries tell us that the word "index" signifies "to point out." An index is usually conceived to be a contrivance to enable one to find something the location of which he does not know. It does this, but if properly made will do much more. It should at least answer with speed and certainty the three questions, "Is there on file anything pertaining to the subject in hand?" "What is there?" "Where is it?" It should in addition give such particulars as scale, if a plan or sketch, date, source of information, and such description as will fully identify the data in the mind of the seeker. A thoroughly worked out index should also have references to pertinent data known to exist in other offices, whether or not such office is allied to the indexing office; data on public record, data contained in professional or trade books or journals, and, in general, to any source of data which are likely to be useful.

3. The form of an index must necessarily vary according to the needs of each particular office and should have the following general qualities: It should be easy to handle, to reduce to a minimum the cost of using it; it should be simple, to enable its use by persons of little education, i. e., the lower grades of help employed in technical or other offices; it should be certain, to enable a person of ordinary intelligence to speedily run down the desired data, and be sure none has been overlooked.

One is tempted to assume that, in this age of cards, no one

would dream of putting a current index into a book. A finished index, e. g., an index to a treatise, is, of course, not to be confounded with a current index, which forms the subject under discussion.

There are just two apparent advantages in a book, namely, the index is always together, and no part can be lost without losing the whole. The first advantage is apparent only, as indivisibility is, in an office of any size, a disadvantage, as only one person at a time can use the index. The second is fallacious in that the loss of any part of an index is in any event only a matter of office discipline; a full drawer of cards cannot easily be lost, and only the indexing clerks should ever be allowed to take cards from their places in the drawers.

The positive advantages of cards really include all the advantages of a good as opposed to a poor index and all that follows may also be taken as an argument for cards (if, indeed, argument is needed). Perhaps the most important of such advantages is that it allows the fullest use of the alphabetical form; this eliminates the loss of time each time the index is used, caused by having to read page after page of irrelevant matter. As such reading is almost necessarily hurried over, and to some extent slighted, the element of certainty is to that extent lost.

Quality, manufacture and size of cards. — The quality and size of cards is of some importance. The paper used should be tough, hard and close grained, heavy enough to handle easily and not too heavy to bend safely.

Perfection of manufacture is very important as it governs the speed and, to some extent, the certainty of the index. The cards should be all of exactly the same size, edges should be clean and square. These two qualifications especially should be insisted upon, even at considerably increased cost. The cost of the stationery is in any event a very small fraction of the total cost of the index, and it is truest economy to buy the very best the market affords. Good cards cost money to make; poor ones are almost worse than none. The same is true of cabinets in which to store the cards: the best are none too good. Size is a matter of personal preference. The writer has used nearly all sizes to some extent, and for indexes proper prefers the 75 by 125 mm. size, a trifle under 3 by 5 in. They are large enough and not too large for comfortable handling.

Arrangement, alphabetical or otherwise. — There is in the human mind a strong tendency to specialize and complicate.

Accordingly we find in much filing that some arrangement other than alphabetical is adopted. The non-alphabetical arrangement presupposes knowledge on the part of the user of the system upon which the index was constructed. This means that each newly employed assistant must learn the system before he can effectively use the index. In case the system is complicated, as a non-alphabetical system almost necessarily is, he must devote a considerable amount of time to learning it, which time has to be paid for by some one and is a dead loss. New men are likely to form a considerable fraction of the force, and the loss of time learning systems of records amounts to considerable. The alphabetical arrangement is intelligible to any one who would have occasion to seek for data in such index, and enables the utilization of low-grade help, — office boys, messengers, etc.

In the indexing of records of an engineering office the question "how many" is sure to arise. The tendency to complicate mentioned above here asserts itself, and there are in some offices as many indexes as there are varieties of records. The writer believes in as few indexes as possible, keeping permanently valuable technical records separated from clerical records and records of ephemeral value. If the filing is done comprehensively, even this division is superfluous, as with cards it is always possible to eliminate obsolete and to insert additional matter.

Speed v. *certainty.* — Speed is important and is attained partly by the free use of guide cards, but more by comprehensive planning in the beginning. Certainty is by far the most important element in the use of an index, and can only be attained by careful, painstaking work by competent persons, in making and keeping it. Who does not know that feeling that the reason for his non-success in seeking is solely that he has looked for the wrong word and that the desired data must surely be at hand. It is still more important in making additions, or in eliminating dead matter, to make sure that nothing has been done to obscure old data, or separate data that belong together. These several forms of certainty involve, after careful work, the intelligent use of cross references.

Cross indexing, or, preferably, cross referencing, is essentially a reindexing under an additional caption; e. g., a bridge plan should be indexed under the name of the street or river, under the number, if numbered, under the name of the township, if named, and under the name of the nearest station if on a railroad, and often under many other captions. Many filing clerks

put the file number on all the cards. This is wrong; the number should appear only under the most important and permanent caption; all the others should refer to that caption instead of to the file number direct. There are several reasons for this: it is sometimes necessary to move records to another place; it is sometimes necessary (convenience may be a form of necessity) to divide or to reindex the data referenced on one card; it is often desirable to eliminate obsolete records. If only one card bears the file number it is very easy to change it or to insert a substitute, or to enter the permanent record of elimination; in such cases the cross references do not need to be disturbed. In case the file number appears also on the cross reference cards, a change of any card must be entered on all, and if by inadvertence one be missed, it will surely make trouble in the future, and may cast a doubt on the correctness of the whole index. These errors are in practice certain to occur; they can be minimized only by a complicated system of recording all cross references. Why do so when the error may certainly be avoided by the simple expedient of numbering a single card? Many cross references mean increased certainty, provided numbers appear on one card only; otherwise many references mean decreased certainty. The writer has often been asked such questions as "Where is the Widow Dean bridge, the Narrow passage ferry bridge, India bridge?" etc. Such questions always indicated the need of another cross reference card. Some one knew the answer; when it had been looked up, and the card inserted, any one could easily find the desired data. It will be objected that it takes time to look for a second card. True, and the extra time is unimportant compared with the certainty that all data on file will surely be found on that card. Suppose a plan turns up (they often do) marked Town River Bridge. The index clerk looks for the card "Town River Bridge," finds it, and enters the plan also on the card marked Bridge No. 217, also on the card with the town name; he forgets that this bridge is also known as Red Bridge, also as Jones Ferry Bridge. Six months later the chief calls for plans of Jones Ferry Bridge; his clerk looks, or the file clerk does, and produces certain plans, not including the one above mentioned. It may be worth thousands of dollars to be able to produce that particular plan in court; unless some one hears of it who happens to have known that the plan exists and was filed and looks it up, the matter will go by default; the production of other plans will in such case obscure the existence of the one really valuable plan. Of course,

instead of a plan it may be a modification of a lease or agreement, or data of agreement as to classification of a cut, or terms of a contract for extras, etc. The main object of an index is to enable one to find data he does not know of, and this object is defeated under the circumstances noted. The probability of such errors is not at all remote. The writer knows of many bridges which are known to different people by as many as four arbitrary names besides the geographical names and number; the same is also true of other structures, farm surveys, etc. He has also known of suits at law lost because of inability to produce plans that afterward were found improperly filed. He has known file clerks to fail on just such a proposition as this.

In case of cards referring to data, plans, etc., in other offices, public record offices, etc., it is usually best not to attempt to give file numbers, but rather to refer to the office only and describe the plan or data, depending on the local index for more particular location. The reason is that files are apt to be changed or may be divided and rearranged. References that are not permanently correct are inadvisable in an index, as they may become misleading.

The writer's experience indicates that the best form for bridge index is as follows: Primary index. Name of street or river. This card is made as nearly complete as possible, e. g.

MAIN STREET BRIDGE 114, MILLSDALE, PA.

Iron — BBW — shop — Bl — 10 shts — $\frac{3}{4}$ in. = 1 ft.—'04	14 – 17 – 2
Abuts and Piers — Trac — 4 shts — $\frac{1}{4}$ in. = 1 ft.—'04	12 – 27 – 14
Floor — RR — Trac — 1 sht — $\frac{1}{4}$ in. = 1 ft.—'05	14 – 25 – 10
Railing — RR — Trac — 1 sht — 1 in. = 1 ft.—'04	14 – 10 – 17
St. Ry. tracks — St Ry — Bl — 4 shts — $\frac{1}{2}$ in. = 1 ft.—'05	14 – 11 – 4
Notes of survey	See survey file
Stresses for class E street car	See computation file

In case there are many plans of one structure the writer has found it advisable to index under the sub-captions, site, masonry, superstructure, tracks, floor, etc., grouping the plans or notes under each sub-caption on one or more cards.

This bridge might have many or few cross references, which should be somewhat as follows: Bridge No. 114, Millsdale, see Main Street; Millsdale Bridge No. 114, see Main Street; Howes Crossing Bridge, see Main Street Bridge 114, Millsdale; Town Road Bridge, see Main Street Bridge 114, Millsdale; Dr. Burgess Bridge, see Main Street Bridge 114, Millsdale, and so forth. Whenever an additional name turns up it should be entered on a new card and referred to the primary card as above.

Cards bearing survey and inspection notes, computations, memoranda, etc., should be cross referenced as above in the general index. This insures that references to all data on any particular subject will be together and none will be overlooked. Reports, requisitions, some letters, etc., if of permanent value, can profitably be cross referenced the same way in the main index. Cards bearing survey notes, etc. (original data), also computations, should, when possible, be kept in a fireproof vault. The general index should be in the most accessible place, in a good light and convenient to get at. The ideal arrangement is a stand on casters or wheels, capable of being easily put into and kept in the vault when the office force is absent.

The elimination of dead matter from a file or index presents some very serious problems. It is so very easy to err in judgment, and, in the interest of convenience, discard data or notes of no apparent present value, which by some unforeseen circumstance become valuable later. On the other hand is the danger of loading down the file with much non-pertinent and obsolete matter. Non-pertinent matter should not get into the file. It sometimes does and with obsolete matter may need to be removed. The writer believes that, as a rule, the index should include all obsolete data on file. The card should be marked "obsolete" or "obs." opposite each such item, and when the card is finally removed it should be kept in a special "obsolete" case or drawer for at least one or more decades.

4. Plan files.

Plans and drawings of all kinds should be filed in drawers or pigeon-holes of suitable size. Any one who has looked for a profile or narrow drawing rolled to, say, 12 in. long, in a 48-in. drawer or space, will not need to be told why. The writer has seen highly-paid men, after the clerks had failed, attack a pigeon-hole containing thirty or forty rolls, and deliberately withdraw each roll separately, expecting to find the desired plan in the back end of the space behind the other plans, and consequently not visible nor accessible without such process.

This fault is usually due to some official or chief clerk, who seldom uses the file, wishing to keep all plans of some class or division together in a certain location. It will readily be seen that if the index is consulted to learn the space and file number it is entirely immaterial in which case or drawer the plan is kept. It should, therefore, be placed where it will be kept most accessible and best protected. A 12-in. roll behind a 45-in. in a 50-in. pigeon-hole is in serious danger, and is itself a serious danger to other plans, as such a file will abundantly testify.

The form of plan files is subject to very wide divergence of opinion; drawers and pigeon-holes seem to be preferred, also racks in some cases. The writer prefers for drawings of reasonable size, say up to 30 by 60 in., a filing case containing drawers or sliding shelves not more than 3 in. deep inside, 2 in. even better, of size to suit the drawings, in which the plans, tracings, etc., are kept filed flat. The drawers should have sheet metal (non-corrosive) corner covers at the back, and springs at the front corners, to hold all four corners of the plans down in place.

For rolled plans of considerable length, similar drawers can be used, but the writer prefers a case of pigeon-holes or shelves with partitions. Each unit space, drawer or pigeon-hole can profitably be made to hold forty or not to exceed fifty sheets or rolls. In some climates it is necessary to provide damp-proof tubes in which to keep the rolls; these may well be of size to hold thirty or more drawings and fit into the filing case. Spaces in all filing cases should not be too deep, and a reasonable assortment of sizes should be provided, as every office needs to preserve plans or prints from other offices, which do not conform to its standards for size. This difficulty is sometimes met by rolling each plan around a stick or tube of standard length, which bears on its end the file number of the plan it belongs to. This has the advantage of keeping the plan in excellent condition, but introduces a chance for error in rolling, inadvertently, a plan on the wrong stick. It is also uneconomical in space and weight, as well as in first cost. Of course expense should be incurred only when the resulting advantage is worth it.

The limit of fifty plans or rolls to each unit is based on observations with the seconds hand of a watch and is, of course, a compromise. The cheaper the labor employed looking up plans, the larger the unit can profitably be made. It is usually of advantage to plan the units of size for fifty plans, and leave them partly filled. Offices having many standard size plans or plans and maps in sets find the shallow drawers, or sliding shelves, a profitable investment, as they save many times their cost in wear and tear of plans.

Numbering file units and plans. — It is usually possible to devise a system of numbers at once so simple that it is obvious and so comprehensive that it will provide for indefinite expansion. The number of digits used should be as small as is consistent with comprehensiveness, and they should be combined to give as many permutations as may be. All present and probable future sub-offices and branches should be included.

A large engineering office or department would naturally include a vault for fireproof storage, a main drafting-room, several specialists' rooms, a clerical office, and, perhaps, a number of local survey or construction offices. Each of these would have a file of plans and records, and nearly every one an index of its own plans and records at least. It hardly needs to be stated that there should also be a general index, accessible to all, and preferably located near the vault and main drafting-room. All these should be covered and differentiated in the first figure or digit of the plan number, e. g., a number beginning 01, 11, 21, might refer to a plan in the vault, in the main drafting-room, in the bridge specialist's room respectively. It would be a large department that would require more than ten such offices or rooms.

The second figure or digit should refer to the filing case or bank of such cases. For any one at all familiar with the file, it would be unnecessary to remember these numbers, as they would represent so large a section of the file that they would automatically represent the idea of the location, leaving the mind free to remember the remaining more characteristic numbers. At the same time, a new employee could soon find any case desired.

In subdividing filing cases or bank of cases, it is usually possible to number by groups of ten, making it easy to locate a given number. Especially when designing such cases this should be kept in mind. It is as easy to divide a given space into ten as into twelve parts, and the convenience so attained is a very great gain, well worth the trouble involved.

The third, fourth and fifth digits, which should preferably be separated from the first two by a dash or hyphen, should represent the ultimate file unit, pigeon-hole or drawer, and give latitude enough with properly arranged cases, for a very large file. Ten thousand file units in a single room are really too many for safety, and before this number is reached the file should be expanded into another room. The final two digits number the individual sheet in the file.

It may occur to some one that it is not desirable to file plans in a drafting-room or a specialists' room, and that all plans should be filed in a vault or fireproof room. There is undoubtedly opportunity for good judgment in deciding which plans to leave out of the vault and which to put in; nevertheless it is now, and without doubt will continue to be, the custom of all or nearly all engineering offices to keep some or many of their plans in such

places, and there is a large class of plans that can be properly so kept. These plans should be indexed in the general index, and should form an integral part of the one comprehensive file. In case plans are moved from one room to another it is not difficult to correct the index if the numbers are properly kept on one card only, as specified above. It need not be said that some one man, preferably a clerk, should have it a definite part of his duties to attend promptly to all filing and changes of file numbers. He should, of course, be governed by carefully drawn rules, should be always and in detail under the direction of the chief draftsman or office engineer, whose time is not thereby wasted, as is often assumed, but is a good, often a very good, investment. One of the ablest engineers known to the writer once told him that " he had only one man good enough to file and index plans, to wit, his highest paid subordinate." In a busy office the chief will rarely be able to find time to actually do the indexing himself; he must then leave the actual work to a file clerk, but should supervise it closely.

The file clerk should preferably put away all plans after they have been used, to insure their getting into their proper places, and should see to it that all tears, rents, folds, etc., are attended to.

The files, and especially the indexes, should be open to the use of all employees of the office, whose duties require use of the plans or data filed. The practice of having files and indexes open to the examination of file clerks only is vicious in the extreme; though fortunately not common, it is still met with often enough to require its mention and condemnation. A file clerk is rarely omniscient; he is usually less intelligent than the average draftsman, who will nearly always be able to run down a desired plan far more quickly and certainly than the file clerk. Complicated or difficult searches for old and poorly indexed plans or data are, of course, possible only where files and indexes are open to the use of the draftsman or specialist who knows what to look for, and the various names by which the data may have been known and filed.

The above does not cover sets of plans like the Geological Survey, for example. The writer prefers for such plans an index sheet showing the boundaries of the various sheets, the plans proper being practically self-indexing by latitude and longitude, or, if necessary, by a letter and number. The reference in the general index would be to the set, and the index number should appear on each sheet of the set, to insure its reaching its proper place in the file.

5. Books are apt to be unsatisfactory from a filing standpoint. They usually contain many subjects more or less closely related to the title; to index them comprehensively requires much time, and anything less falls short of what an index should be. A careful reading of the book is usually a prime necessity, and to be satisfactory this and the indexing must be done by some one conversant with the subjects treated. The bulk of the indexing proper is cross referencing. Periodicals are not so bad, as the amount of pertinent matter is less. Trade circulars and catalogues are often very complex, and only rarely contain permanently valuable matter. Those that do will repay careful indexing and cross referencing; some of the data they contain may be invaluable.

Documents are analogous to plans. Large files of deeds, leases, etc., can sometimes be profitably indexed on a map of suitably small scale. In such case the general index should have a reference in general terms, e. g., "Deeds," see Deed File, Map No. 26 — 32 — ; Leases, see "Deed," etc. (the file occupying the unit 26 — 32 —), the individual deed, lease or whatever it is, being filed by a number on the index map. Isolated documents should be treated the same as plans.

6. Computations have in the past usually been kept in books, and more or less, usually less, comprehensively indexed. The writer believes there is a better way, and has seen it in use in a very few offices. Computations should be made on paper of standard size to fit standard filing cases — typewriter size is about right. The computations proper, with the data, diagrams, sketches, reference to notes, etc., all on the standard paper, ruled or plain as needed, are held together by a suitable fastener and kept in a self-indexed, cross-referenced file. Many years' experience has taught the writer that, whenever possible, copies of all original data, memoranda, etc., should be filed with the computations, also copies of diagrams used, or at least a reference to some other computation where the same diagrams have been filed. The writer has had occasion many times to refer to old computations of bridge stresses, where no definite load diagram was referred to. It was a long, tedious job to work it back from the figures given. He has of late years made it a practice to keep load diagrams, tables, etc., on tracings of about 5 by 7 in., a print being gummed at one end and fastened into the computation book where needed; of course this in an office where the rules required books to be used.

7. Since the above was first written, some five years ago.

there have been a number of systems for indexing proposed in the technical press, many of which the writer has seen and studied. Of these many are excellent provided the index is of limited scope, and is to be used only by highly trained men. The writer has seen none, and has seen mention of none, which meet the fundamental requirements laid down above, viz., simplicity sufficient to allow its efficient use by relatively unintelligent help, certainty as outlined above, and wide adaptability.

[NOTE. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by November 1, 1909, for publication in a subsequent number of the JOURNAL.]

THE FILING SYSTEM OF RECORDS IN THE ENGINEERING DEPARTMENT OF SALT LAKE CITY.

By O. H. Skidmore, Member Utah Society of Engineers.

[Read before the Society, March 19, 1909.]

To properly understand this system, it will be necessary to give a slight outline of the organization of the department, which consists of the following:

The City Engineer as the chief, and a Principal Assistant Engineer; then four division assistants, having charge of four separate divisions, namely:

1. The street division, taking care of paving, sidewalk construction and grades for same.

2. The sewer division: the construction, operation and maintenance of sewers.

3. The water-works division; the construction of water-mains and superintendence of the city's canals and waterways.

4. The electrical division locates poles and supervises the work of the various public-service corporations operating under franchises in the city in the laying of their underground conduits and stringing of wires, and also looks after such electrical equipment as is controlled by this department.

Besides these divisions, there is a drafting room, in charge of a Chief Draftsman; a computing room, in charge of a Chief Computer; and the public office, in charge of the Chief Clerk, who deals with the public and has the general supervision of the clerical force. The filing department is carried on in a commodious vault by a head filing clerk and assistant. The department operates a cement testing laboratory, in which samples of all cement used in municipal contracts are tested, and no small amount of custom work is handled; and also a blue print room is maintained, in which prints of all the drawings of the department are made.

Early in the year 1906 Mr Kelsey found that, with the beginning of the era of improvement, and the large amount of records already in the vault of the department, a new, up-to-date system of indexing and filing was needed. The office became an office of record, and a precise system of keeping these records was an urgent need. After careful study and few experiments, the present separate " leaf " system was matured.

Beginning in the field, with the completion of the day's work such notes as are taken are the next morning checked in the computing room, given their account numbers and sent to the vault for filing. With the mention of account number the system has its beginning. The department has issued for the employees a small paper volume containing the different account numbers and the account they represent.

Under the head of Contingent Fund are the numbers 1 to 20; these include expense, resurvey, private surveys, subdivisions and additions, and the other departments which this office assists with engineering.

Water Supply, numbers from 21 to 30, includes the accounts of the water resources of the city with the irrigation maintenance and construction.

Water Works, numbers from 31 to 35, includes the supply mains, water-works department construction and maintenance and the water-main extensions.

Streets and Sidewalks number 36 to 45, and include all the extensions pertaining to the improvements of the streets.

Sewers and Drains number 46 to 50, and include the drainage and sewer departments, both construction and maintenance, and the sewer extensions.

From this it can be seen that each principal account has its own account number. Now with the principal account number each one has its sub-accounts, and in order to clearly show such, let us take the water-works account.

Covering water-works proper, the account number is 31 to 31–Z, taking in the alphabet; supply mains, 32; new water supply mains, 32–B; city creek pipe line, 32–J, and so on to 32–Z. Water-works department (maintenance) is 33 and sub-accounts contain grades and lines for hydrants and pipes, city maps, electrical survey of water-pipe system, etc., to 33–Z; water-works department (construction) is 34, with sub-accounts under plans, estimates, etc.

Water-main extensions have the number 35, with the particular extension number as the sub-head. Water-main Extension 181 would be accounted for as 35–181. These accounts are carried through the bookkeeping and all parts of the office work.

When the City Council makes the appropriation for the department it is divided up among the various account numbers and their subdivisions, which amounts are placed to the credit of each account number, and expense connected with such work in material and time is charged out as work is done.

To simplify matters the principally used accounts have

special colors designated to them, and are used in the field notes and folders for letter and estimate filing. Water-main extension notes and all folders pertaining to water works are light blue. Paving extensions and their folders are pink. Sidewalk extensions and their folders are coffee color. Sewer extensions and sewer department work, light green. Notes and folders pertaining to the electrical department are light gray. Private surveys are corn color. Street profiles are tuscan.

When the notes for filing reach the vault, the filing clerk notes the account number placed on the notes by the checker and places them in the cabinet drawers designated by such numbers. The drawers have subdivisions in them corresponding to the subdivisions of the accounts before mentioned, and are easily identified.

The forms of field notes are divided into as many as are necessary to complete any class of work, being single sheets folded 16mo size. The first page has a blank for account number, extension or permit number, total of particular surveys, remarks and names of field party and date. The two inside pages are regularly ruled for either level or transit notes. The last page is left blank. Where special work is necessary, as in the measurement and location of the hydrants and valves, there is a specially ruled form with proper headings to fit such work. A copy of the inspector's notes is also made up on these special leaves, and is ruled accordingly. With the completion of an extension or some special work, these field and inspector's notes are bound in book form and preserved for record.

Following this same system of record, all the correspondence of the department pertaining to each account is similarly filed in folders, cardboard front and back, and bound to it with fasteners. Carbon copies of all outgoing correspondence are also filed, and a complete record of the accounts can be had by referring to these folders, which bear the number of their account.

All the computations are made in the computing department, and here a great number of ruled forms are used, special care being taken to have all forms of either of the two sizes for filing, standard letter size or the 16mo size of the field forms. In this department all the records and computation of the water supply are made, and these require quite a number of forms for stream measurement, and those necessary for the Utah Lake pumping plant, the city engineer being the representative of Salt Lake City in the Associated Canal Companies. In making up the partial and final estimates the computers use small forms (note size) for their computations and estimates,

and these, after being checked, go to the stenographer. All the estimates are rechecked by the assistant engineers and then await approval. Located in the computing department there is also a Challenge-Gordan press and complete outfit. This is used for lettering tracings and the indexing systems.

The most complex problem that confronted the office was to find a simple yet efficient system to file the tracings and drawings. There are at the present time 4 125 tracings and 1 058 drawings.

Five sections of steel cases were purchased, each having ten drawers and one drop door compartment. The drawers take any drawings up to 42 in. by 42 in. and hold with ease an inch and a half of tracings laid flat. The drawings and blue prints are filed in wooden cases similarly constructed, and rolls, such as large maps and cross sections that cannot be filed flat, are placed in the large lower spaces fitted in both wooden and steel cases with drop door fronts. The fronts of the drawers are provided with card slides for the account number, and the drawings and tracings are filed according to the account number system previously mentioned. These tracings and drawings are indexed according to the same system, and, turning to the account number, one can readily find at a glance the drawing or tracing desired. To further facilitate finding drawings or tracings they are also cross indexed by title and account number.

In connection with the department, and most valuable for record purposes, is a complete photographic equipment. As the work on any public improvement is susceptible to many law suits, just and unjust, photographs are taken during the various stages of the work. These progress photographs are undoubtedly the best witnesses the city can have. There are at present on file, indexed similarly to the other records, 1 873 negatives in two sizes — 6 in. by 8 in. and 8 in. by 10 in. These photographs have paid for themselves many times over by the winning of suits by the city through these mute witnesses.

Aside from the tracings and drawings are the Plat books which have been made both of the blocks of the city and the entire sewer systems. The block Plat books are made up of heavy drawing paper mounted on canvas, and bound with hinge binding so that the pages will always lie flat. All pages have numbers corresponding to the block number, and the plat of the book is first outlined on the page, showing all the monuments on the four streets bounding the block, together with the ties for same. Then, as private surveys or resurveys of the

city are made, all such are entered upon the outline drawings of the blocks. Separate books are made for each plat division of the city.

The sewer plat books, of which there are now twenty-five, are made in the same manner as the block books, and have along the center of the page the plan of both sides of one block of a street, showing the monuments at the two intersecting streets at each end of the block and their pluses from the base line, at the section of the city in which they are. The sewer line is drawn in, showing the location by pluses of all Y's and manholes. At the top of the page is a profile of the sewer, showing the grade and rate, manholes and ground levels of the one side of the street, and at the bottom of the page is the profile of the opposite side of the street. These books are arranged in districts and numbered according to their respective numbers, carrying on the front page an index to the blocks which each page covers. In addition there is a map of the city, showing all sewers, drawn in in colors and a number corresponding to the number of the book in which they are to be found.

All permits which are issued by the department, such as sewer connections, pole permits, house numbers, cement tests and the like, are typewritten on printed forms in duplicate, the original remaining in the office and the duplicate going to the applicant, who signs a printed receipt in duplicate which is on the form of permit of both original and duplicate. After all records, such as these permits, note sheets, letters, calculations, estimates, and in fact all but drawings and tracings, become a year old, they are bound in permanent bindings for record. These bindings are lettered with the account numbers and subletters to which they belong, and are placed in glass-front cases. These bindings also carry the color of the class of work to which they belong, thus making the records in all the stages quickly recognizable and showing by their distinguishing color, number and letter to what part of their particular division they refer.

The system has been developed and elaborated during the past three years under the personal supervision of Mr. Louis C. Kelsey, the present city engineer, to whom the credit is due for one of the best and most complete systems of records, if not the best, in the country.

[Note. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by November 1, 1909, for publication in a subsequent number of the Journal.]

INDEXING USED IN THE ENGINEERING DEPARTMENT OF THE TOWN OF BROOKLINE.

By Henry A. Varney, Member Boston Society of Civil Engineers.

The system of indexing now in use in the Engineering Department of the town of Brookline was devised in the year 1902, after considerable study of the methods used in several of the larger municipal engineering offices in New England.

Everything is indexed under the name of the nearest street and also cross indexed under every other street referred to in any way. Plans, notes and documents are indexed separately and at present there is a fourth index for "Land Plans," which, however, can be combined with the main plan index at any time.

Standard sized flat plans are always used when feasible and are filed in shallow drawers and numbered consecutively in addition to the designations explained below. Not more than fifty plans are ever filed in one drawer. When large plans cannot be avoided, they are rolled and filed in pigeon-holes or plan tubes.

"Land Plans" are copies of plans recorded in the Norfolk Registry of Deeds relating to property in Brookline. They are made on tracing cloth and are always filed flat.

Drawers are lettered and numbered, the letter referring to the the bank or section of drawers, and the number to the position of the drawer in the section. It might possibly be better to number the drawers consecutively and so do away with the section letter, as plans are sometimes put away in the wrong section by mistake and so lost for an indefinite period, and again, it makes one more designation to remember when looking for a plan.

White cards of medium weight are used in indexing, about 3 in. by 5 in. in size, with tabs to designate the different classes of work. No colored cards are used except for guides and subguides, the former being buff and the latter blue. The tabs are of such size as to allow space for twelve classifications. For the plan and note index ten are used at present, as follows: Map, street, sewer, drain, park, building, bridge, land plan, water and miscellaneous. By the use of these tabs it is possible to locate the required card very easily, thus saving time and preventing the index from becoming unwieldy with growth.

On plan index cards the street name is written across the top, then below this at the left is a space for the filing numbers, and at the right, room for a description of the plan and still lower down are ruled places for the date, scale, engineer and material. Only one reference can be put on these cards.

For the Land Plan index the street name is placed in the upper left-hand corner, and the side of the street on which the property is located, at the right. The next line below is for the names of the streets between which the property shown is located, and the lower part of the card is divided into vertical columns for the owner's name, engineer, scale, date and place of filing.

In connection with the plan index a " Drawer " book and " Accession " book are used.

The Drawer book is for the purpose of showing what spaces are available in drawer or pigeon-holes for plans about to be filed. Two pages are reserved for a drawer and are headed with the section and drawer number. Down the left side of each page are the numbers 1 to 50, with an additional column for the accession number, and to the right of that column a space for a brief title.

The Accession book gives all the information relating to a plan and enables it to be located if the index card is misplaced or lost. In this book is recorded the full title, scale, date, size and material of each plan under an individual or " accession " number; also the initials of the assistant by whom the survey was made and plotted, the purpose for which it was made, and where and under what streets it was filed. Every plan made by the department is given an accession number whether it is to remain in the office or is for record.

In indexing notes they are arranged under subjects in addition to the tab classification. Calculations, estimates, levels, profiles and surveys are some of the " subjects," about twenty being used. This classification is written in the upper left-hand corner of the card, the opposite side being reserved for the street name. Below are vertical columns for the date, book and page and a brief description. The vertical ruling makes it possible to put several references relating to the same subject and street on a card, thereby reducing the number of cards in the index.

The loose leaf system has been adopted for street line and grade work and for sewer construction, and this has cut down the growth of the note index, as the loose leaves are filed in the same manner as cards behind the proper street name and do not have

to be indexed. If the loose leaf idea was applied to all classes of notes, calculations, estimates, etc., it would eliminate the necessity of a note index except, of course, for the old books.

The document index is for all correspondence, reports, estimates, bids, descriptions, specifications, etc. Everything is indexed under the name of the street to which it refers, as in the plan and note index, and, in addition, the correspondence is indexed under the person's name from whom the letter is received or to whom it is written. These latter cards are filed in a separate drawer. The tab card system is used here also, the tabs referring to the above-mentioned subjects. The cards are further classified by the use of sub-guides cut in "sevenths" and labeled "street," "sewer," "drain," "park," "water," "bridge" and "miscellaneous." If the document to be filed was a description of a street location it would be indexed on a "description" tab card and placed in the index behind the sub-guide marked "street." A space is reserved at the top of the card for the street name, a vertical column ruled down the left-hand end for the date and a similar one down the opposite end for the folder and document number. This leaves a generous space between for a description of the document.

The documents are filed by the vertical system, in legal size folders numbered consecutively. No more than fifty sheets are allowed in a folder and each paper is stamped with the number of the folder as well as an individual number. This enables one to locate any document exactly and if any are missing there is no chance for speculation as to whether or not there ever was such a document filed there.

The number of plans in the department has more than doubled since the index was started, but any required plan is as quickly and easily found as at first; in fact, the system, throughout, has proven very satisfactory and capable of indefinite expansion.

[NOTE. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by November 1, 1909, for publication in a subsequent number of the JOURNAL.]

FILING AND INDEXING DATA IN THE OFFICE OF THE CHIEF ENGINEER OF ELEVATED AND SUBWAY CONSTRUCTION, BOSTON ELEVATED RAILWAY COMPANY.

By Herbert C. Hartwell, Member Boston Society of Civil Engineers.

[Read before the Society, January 27, 1909.]

In preparing this paper, the writer has attempted only a brief outline of the system of numbering, filing and indexing data in the office of the Chief Engineer of Elevated and Subway Construction of the Boston Elevated Railway Company.

In this office all plans on file are divided into four classes, namely:

Office Record plans, which include all plans drawn by this office.

Shop plans, which are those plans drawn by the various contractors and submitted for approval.

Architectural Full-Size Detail plans of the various buildings.

Miscellaneous Foreign plans, which include plans of various works received from other offices.

The last three classes of plans, namely, the Shop plans, Architectural Full-Size Detail plans and Miscellaneous Foreign plans, are not numbered by this office, leaving the Office Record plans as the only plans bearing the file numbers, and for convenience of filing and handling, standard sizes for these plans were adopted as follows:

Record size	11 in. by 14 in.
Demy size	15 in. by 20 in.
Imperial size	23 in. by 31 in.
Double Elephant size	27 in. by 40 in.
Rolled plans to be made even feet in width and varying in length.	

Numbering and Filing of Data.

In numbering the Office Record plans, each size was given a separate series of 5 000 numbers, as follows: Record size, 10 000 to 14 999; Demy size, 15 000 to 19 999; Imperial size, 20 000 to 24 999; Double Elephant, 25 000 to 29 999; and Roll plans, 30 000 to 34 999. By this method a number of a plan indicates its size, and that, in turn, the size of the plan case in which it is filed, and this often enables one familiar with the office to find plans without consulting the card index.

Each size of the Office Record plans is classified and filed by subjects, such as "Column Foundations," "Land Takings," "Special Trackwork," etc. Each classification of each size of plans is given a sub-series of numbers within the limits of series corresponding to its size. The limits of these sub-series of numbers are determined by the number of plans that can be filed in the box, drawer or pigeon-hole, as the case may be.

Plans of the Record and Demy sizes are filed in boxes holding 100 tracings; those of the Imperial and Double Elephant sizes, in drawers holding 50 tracings; and the Roll plans in pigeon-holes containing 10 tracings each. Each box, drawer or pigeon-hole is of a separate classification, marked with its title and sub-series of numbers.

As before stated, the Shop plans, Architectural Full-Size Detail plans and Miscellaneous Foreign plans are not numbered by this office, but those pertaining to one piece of work are bound together and have a tag attached, stating to what work they refer, and are filed separately in a special case.

Loose-leaf plan catalogues titled, "Record plans," "Shop plans," "Architectural Full-Size Detail plans," and "Miscellaneous Foreign plans," contain the numbers, descriptions and any other identifying marks of all plans on file. It is from these catalogues that the plan index cards are written.

In numbering the field and computation books, each division of the work was given a separate series of 100 numbers, as, for example, Roxbury division, 500 to 599; Atlantic Avenue division, 600 to 699. By this system of numbering, the books can be readily separated into their respective divisions, which is very desirable whenever it becomes necessary to establish field offices along the line of work.

The photographic negatives are numbered in the same manner as the field and computation books, namely, by the geographical division of the work.

Field and computation book catalogues similar to the plan catalogue are kept, stating the nature of the contents of the books. Photographic negative catalogues, giving the number, date and description of the negatives, are also kept in the same form.

Indexing of Data.

The card indexes differ from many others only in the size of cards used, which is $8\frac{1}{2}$ in. by 7 in.

The plan index consists of blue header cards marked with the titles of the grand divisions of the plans, such as "Elevated

Steel Structure," "Passenger Stations," "Power Stations," "Track System," "Rolling Stock," "Power Transmission," "Car Houses and Repair Shops," etc., and white tab cards bearing numbers representing the subdivisions of these grand divisions. (Fig. 1.)

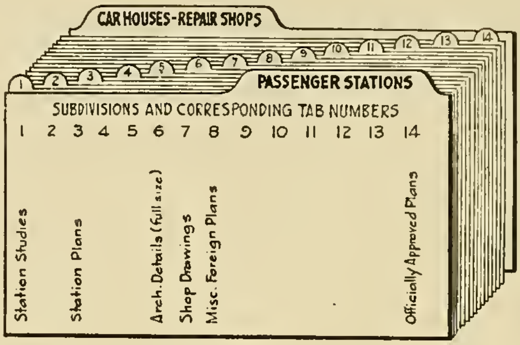

FIG. 1

On the blue header cards marking the grand divisions are found the titles of their subdivisions and their corresponding numbers. On the white tab cards bearing numbers indicating the subdivisions are found the description and location of the individual plans.

To illustrate the use of the plan index, take, for example, the grand division titled, "Track System," and we find upon the blue header card bearing this title some of the titles of the subdivisions and their corresponding numbers to be as follows:

No. 1, curve details; No. 2, track layouts; No. 5, special work; No. 7, shop plans; No. 8, foreign plans; No. 14, officially approved plans.

Suppose one wishes to find the shop drawings of some particular switch. Either at a glance, or by the process of elimination, one determines the grand division titled "Track System" as the classification including the plan sought. Upon the blue header card titled "Track System" is found among the titles of subdivisions that of "Shop Plans," which is numbered 7, indicating that the description of the shop plans of all track work is to be found upon the white tab cards numbered seven filed under the grand division of "Track System."

If the desired drawing is that of a switch of the Brooklyn Elevated instead of the Boston Elevated Railway, one would consult the tab cards numbered 8, which number corresponds to the subdivision of Foreign plans, as all plans of the Brooklyn Elevated Railroad are classified as Foreign plans. Again, if

one wished to know which plans of trackwork had been approved by the various city or state officials, he would find the information upon tab cards numbered 14, whose corresponding title is that of "Officially Approved Plans."

In the plan index, the same tab number is made to indicate the same subdivision under all the grand divisions as far as possible. For example, tab cards numbered 6 indicate architectural full-size details in all the grand divisions where applicable; number 7 indicates shop plans; and number 8 indicates miscellaneous foreign plans. By this method of using numbered tab cards to indicate subdivisions it is only necessary to consult those cards bearing the number representing the particular subdivision desired, and the handling of all others is, therefore, eliminated.

The computation book index consists of the same grand divisions, and is arranged in the same general manner as the plan index.

The field book index differs from the plan and computation book indexes in that street names alphabetically arranged appear on the blue header cards in place of the titles of the grand divisions. The numbers on the white tab cards which are filed under the blue header cards bearing the street names indicate the nature of the notes; for example, tab cards No. 1 always indicate survey notes; tab cards No. 2 always indicate level notes, etc., in place of the subdivisions of the plan index. (Fig. 2.)

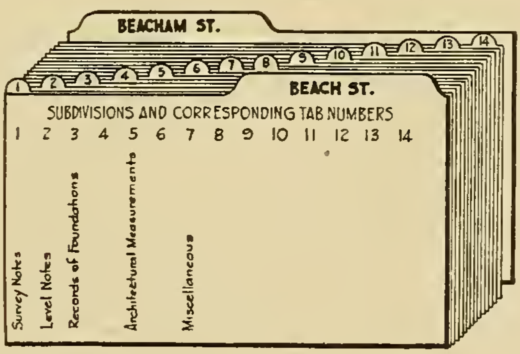

FIG. 2

The photographic negative index consists of loose-leaf books. The books are marked with the titles of the grand divisions of the plan index so far as applicable. In these loose-leaf books are inserted white fly leaves titled with the subdivisions of each book, and under each subdivision are filed blue prints of all

negatives belonging to that subdivision, chronologically arranged. For example, taking book titled " Passenger Stations," one will find upon the white fly leaves the names of all the various stations under which will be found chronologically arranged blue prints of all negatives taken showing that particular station from some time previous to construction to date of last negative taken. On these blue prints appear the number, date and a brief description of the photograph.

In preparing so-called subject indexes of this kind, it is important that the titles of the grand divisions be very carefully selected, so that there may be no doubt as to the grand division under which any plan belongs. Having the grand divisions well defined, the nature of the individual plans suggests titles of the subdivisions.

[NOTE. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by November 1, 1909, for publication in a subsequent number of the JOURNAL.]

PREPARATION OF PLANS AND THE ASSESSMENT OF BETTERMENTS IN BOSTON, AND THE LAWS COVERING THE SAME.

By Frank O. Whitney, Member Boston Society of Civil Engineers.

[Read before the Society, February 10, 1909.]

The laws relating to the laying out of streets and the assessment of betterments in Boston have been subject to various changes during the past twenty years.

Previously to 1891, streets were laid out by the Board of Street Commissioners, and assessments were levied at their discretion; their authority being prescribed by the general betterment law. In those days it was the practice to levy assessments only on improvements of large importance, in cases similar to the extension of Washington Street to Haymarket Square, and the widening and extension of Devonshire Street, and to leave the ordinary street laying out cost to be borne by the city.

In 1891 the Board of Survey Law was enacted, which provided that the whole cost of streets laid out under that act should be assessed upon the abutters. As that law did not repeal the general law, the board were still permitted to continue under the old law where the new one did not apply.

Later, the Board of Survey Law was amended, limiting the assessment to 50 per cent. of the cost, and in no case to exceed the real benefit.

In 1906, a new street law was passed for the city of Boston, providing that all streets should be laid out and assessed under it. This law was similar to the amended Board of Survey Law and is the one under which the city of Boston is now operating. It is the purpose of this paper to describe the details of its practical working. The law in detail may be found in the Acts of the Legislature of 1906, Chapter 393.

When a petition is received by the street commissioners, asking that a street be laid out as a public way, a plan is prepared showing the dimensions, width and grade of the proposed street. The plan also shows any parcels of land to be taken in such detail that deeds may be made of each ownership. All buildings and fences are shown in plan and profile with sufficient accuracy to estimate any damages occasioned by either line or grade.

If the Board of Street Commissioners are of the opinion that

the improvement should be made, whether consisting of the laying out, relocating, altering, widening or discontinuing, with or without construction of sewer, or of changing the grade, or constructing with or without sewer, they appoint a time for a public hearing, and cause a notice of the same to be published twice a week for two successive weeks in two daily papers published in the city, the last publication to be at least seven days prior to the time fixed for the hearing.

After the hearing the board may pass an order for making the improvement. At the same time the board pass another order, in which they determine and award the damages to be paid by the city to each person whose property is taken for the improvement.

These orders are null and void unless they shall be approved in writing by the Mayor within three months after first publication of the notice; and if so approved they are recorded in the records of the board, take effect and are carried out. After the approval by the Mayor, the order for the improvement is recorded in the Registry of Deeds. Any person dissatisfied with the award has recourse to the Superior Court.

The superintendent of streets is authorized to carry out the orders of the Board of Street Commissioners in the manner prescribed in sections three and four of the law.

At the time of passing the order for the improvement, the board estimates the probable benefit to each parcel of real estate, any part of which lies within 125 ft. of the improvement, beyond the general advantage to all real estate in the city. For this purpose a plan is prepared showing all estates within the assessable area.

Within two years after the completion of the improvement the board are required to determine the actual benefit to each parcel and determine the assessable cost. If the benefit warrants the same the board may assess one half of the cost upon the property benefited, but in no case shall the amount assessed exceed the original estimated benefit.

In making up the cost there are excluded the cost of sewers above $4. per linear foot, all surface drainage, water pipes and gas pipes.

These assessments may be paid in full or divided into ten annual installments with interest. Assessments and damages bear interest at 4 per cent. per annum: in the case of damages, from the date of taking; and for assessments, thirty days after

the assessment is made. The assessment becomes a lien upon the property from the date of the first advertisement.

No person has a right to open a private way for travel in the city of Boston unless its location, direction, width and grades have been approved by the Board of Street Commissioners and the Mayor.

All city departments are prohibited from placing any public work of any kind in any way opened contrary to law.

As an illustration of the method of procedure, I have selected the case of Oakridge Street, Dorchester, as a typical street containing all the conditions ordinarily met with. This street existed as a private way leading from Morton Street. The Board of Street Commissioners laid out this street and extended it through private land to Codman Street.

This work was the result of a petition to the board signed by a large number of interested parties.

Upon the receipt of this petition, the commissioners caused a plan to be prepared showing the direction, width and grade of the proposed improvement, together with the relation of the abutting property to the same, with sufficient information to show the grade damages and amount of land to be taken.

An order of notice was then issued, September 12, 1906, setting September 26, 1906, as a date for a public hearing. This notice was duly advertised four times in two daily papers published in the city of Boston.

As a result of the hearing, the Board of Street Commissioners passed the order for the laying out of the street, October 5, 1906, which was approved by the Mayor, October 17, 1906.

This order and a copy of the plan was recorded in the Suffolk County Registry of Deeds, October 23, 1906, and the way became a public street.

Simultaneously with the passage of the order an estimate of the damages incurred and the estimated benefit to parties concerned was transmitted to the Mayor for his approval. The damages were estimated from data shown on the plan and an inspection of the ground. The estimated benefit was apportioned from data shown on a plan prepared for the purpose. The estimated expense was made up by adding the amount of damages allowed by the board and an estimate of the cost prepared by the superintendent of streets; viz.: $1 075.50 and $8 800, making a total of $9 875.50. The statement of the superintendent of streets was furnished upon request of the board previously to any public action.

The street was then turned over to the superintendent of streets to construct, and the damages were settled by the Board of Street Commissioners.

After the completion of the street the superintendent of streets certified to the actual cost, this amount, $7 771.71, together with the damages paid, $1 075.50, totaling $7 946.21, being the cost of the improvement. Fifty per cent. of this amount, or $3 973.60, became the assessable cost.

The board then proceeded to assess upon the interested parties such amounts as in their judgment were warranted by the benefit, which in this case was a little less than 50 per cent. of the cost.

I have discussed only the working of the Boston law, as that is the only one under which the city is authorized to operate; but I think the general law as applied to other cities is different only in a few details, the essential working of which is practically the same.

The following table gives the number of streets assessed for ten years from 1897 to 1906 inclusive, together with the cost and assessment.

Assessments.

Year.	Streets.	Cost.	Assessment.	Special Betterments.
1897	5	$47 741.84	$47 741.84	
1898	7	81 465.85	60 367.69	$367 440.00
1899	8	81 520.32	76 273.84	
1900	27	399 010.27	330 376.15	1 387 512.79
1901	11	44 265.43	36 281.96	
1902	55	1 887 353.30	593 433.09	
1903	33	*2 461 559.46	797 302.53	
1904	25	323 285.19	127 703.88	
1905	34	522 238.10	165 831.17	
1906	6	542 737.38	81 851.43	
	211	$6 391 177.14	$2 317 163.58	$1 754 952.79
Reassessed,		*268 354.11	236 027.56	338 878.52
		$6 122 823.03	$2 081 136.02	$1 416 074.27

[Note. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by November 1, 1909, for publication in a subsequent number of the Journal.]

Editors reprinting articles from this JOURNAL are requested to credit the author, the JOURNAL OF THE ASSOCIATION, and the Society before which such articles were read.

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OF

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WORK OF COMPLETING CHALMETTE MONUMENT.

BY ALFRED F. THEARD, MEMBER LOUISIANA ENGINEERING SOCIETY.

[Read before the Society, June 14, 1909.]

ABOUT three years ago, at the request of one of my personal friends and of the ladies who form the membership of the United States Daughters of 1776 and 1812, I made an investigation of the then existing conditions at the Chalmette Monument. I studied closely the conditions under which the work had been planned and partly executed, and thereafter submitted a written report covering the result of my investigation and making some suggestions as to the continuance of the work. These suggestions were submitted to and approved by these ladies. I never even suspected at the time that I was about to put myself in a peck of trouble.

What I had done was done because of my sympathy with those who were striving to make this momument a fitting tribute to the memory of the heroes of 1815, and I felt honored to have been called upon to help along this good cause. But the friendship of the gentleman who had spoken to me made him look upon my work as through a magnifying glass, and he so impressed the ladies with the importance of my suggestions that my report was used as one of the documents to solicit federal aid and to support the strong case admirably presented to Congress by their association. Within fourteen months after the first investigation, I think in March, 1907, Congress appropriated the sum of $25 000 to cover the entire cost of the improvement recommended. The victory which was won proved the influence of the distinguished

ladies who had helped this cause, had gone to Washington, appeared before the committee of Congress, and, by an eloquent appeal, obtained a favorable report and finally secured this appropriation which made the work possible.

Some few months later, in June, 1907, I was agreeably surprised and very highly flattered when Major McIndoe, on behalf of the Secretary of War, asked me to prepare plans and specifications for the work contemplated under my original suggestions, and fixed the terms of my compensation for professional services.

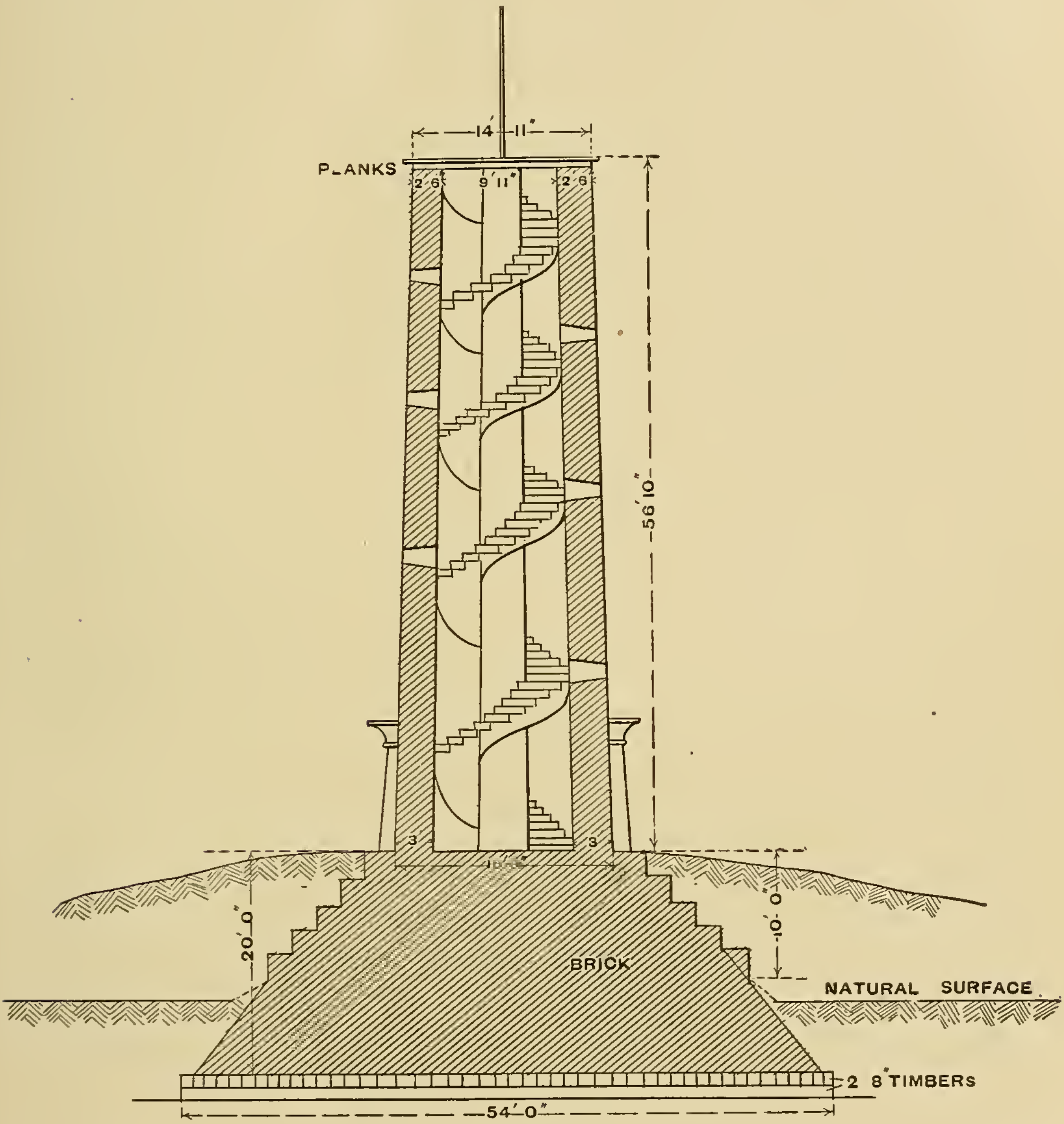
About the first of July, I commenced a thorough investigation of the actual conditions at the monument. Considering it absolutely necessary from a professional standpoint, I had, at my own expense, excavations made, and exposed the entire west side of the foundations down to the bottom. I desired to ascertain the exact condition of these foundations before attempting to increase the load then carried. Of course I felt reasonably safe, because this unfinished shaft, built within a few hundred feet from the river, had withstood the fury of the elements for over fifty years, — quite a severe test, particularly for the parts exposed to the weather. And if any signs of settlement were apparent, they were so slight that they need not be considered.

Many of you know how the Chalmette Monument was originally designed by Newton Richards; how his plans were adopted by the Jackson Monument Association in May, 1855; and how a contract for the erection of the monument was awarded to Newton Richards and John Stroud & Co., in June of the same year.

The designs submitted, the original being at present in the notarial archives in this city, covered four distinct plans numbered from " 1 " to " 4 " inclusive, graded in cost and finish from an expensive and elaborate monument nearly 200 ft. in height to a plain column barely 60 ft. high; the one being of proportionate size and finish, with an ornamental capital; the other being devoid of any ornamentation, with a bare and simple appearance.

The design selected (marked " 2 " on the original plan), while less elaborate and expensive than the most costly, was undoubtedly, in my opinion, the most appropriate and the most beautiful. It consisted of a plain shaft, 142 ft. high, resting on five steps, each 2 ft. high, and starting about 2 ft. 6 in. above the natural surface of the ground; the shaft to be 16 ft. 8 in. square at the base, and 12 ft. 6 in. at the top; the base of the shaft on the four faces to have corniced projections surmounted with

sculptured emblems; one of these to serve as an entrance to a spiral stairway leading to a chamber at the top; the stair being lighted by small openings at regular intervals; both shaft and base to be faced with marble.



SECTION OF MONUMENT AS IT WAS.

The work had been partly erected, and a careful examination confirmed me in the belief that what was done had been done in accordance with the specifications annexed to the original contract, and with a view of the carrying out of the work as originally contemplated. Indeed, the foundations, as specified, were to consist of a double floor of 8-in. timbers laid transversely 54 ft. square; then a thickness of 20 ft. of brick work, 53 ft. square diminished by gradual offsets of 2 ft. 6 in. each, at every

2 ft. above the natural surface, to a square of 22 ft. at a point 3 in. below the marble facing of the shaft.

I copy the original specifications for this item:

> A flooring of timber is to be laid in the bottom of the excavation to start the brickwork upon. It is to be 54 ft. square, formed of two courses of sound timbers, each to be 8 in. thick, one course to be laid transversely across the other and to be fastened at every alternate crossing, both courses, with tree nails of $1\frac{1}{2}$ in. diameter. The pieces of timber all to be straight, laid close together and thoroughly rammed down to a solid, even and level bearing and the joints, interstices if any, thoroughly filled with mortar in each course as it is laid. The cross timbers will be laid under the longitudinal timbers on one side and upon them on the opposite side of the foundation, so that the long timbers may all cross each other at all the four corners of the foundation. The timbers to an extent of 12 ft. square in the center of the floor are to be disconnected from the surrounding ones.

I have read this particular description because I wanted you to note the peculiar provision for any future movement or settlement by this independent platform, 12 ft. by 12 ft., in the center of the square area.

The shaft was 56 ft. 10 in. above the line at which the top of the step would meet it; this step or base being, if completed, about 12 ft. 6 in. above the natural surface. From the natural level to this point, a mound extended around the base of the monument, with a diameter of about 185 ft. At the foot of the mound was a ditch which drained the entire plot. At the top of the shaft the very crude wooden cover (an ordinary flooring on five pieces of 4 in. by 12 in. laid crosswise) showed conclusively that neither the designer nor the Jackson Monument Association ever intended to leave the work at this point. The large mound which covered the entire base had been placed there, a few years before 1906, not to form part of the ultimate structure, but merely to serve as a protection for the uncompleted base, and no doubt accomplished its purpose.

I was pleased to find the foundations in a perfect condition. The timbers were in a remarkable state of preservation and now, nearly two years since they were secured, I have here for your inspection a few chips taken from these timbers which I consider quite interesting. Some of those who have examined these samples have differed as to whether they are cypress or pine. I believe they are good cypress.

The first two or three courses of brick had been exposed to the weather for a long time before the mound was placed over

them and the mortar was either entirely removed from the joints or crumpled into a soft powder, but when these three outside courses were removed the brickwork was in a perfect condition. The marble facing of the shaft was very much soiled from its long exposure to dust and rain. The visitors to the Chalmette Monument, perhaps through a desire of becoming famous by their close, very close, association with this monument, or probably through their craving for the slow destruction of all monuments, — these visitors, numbering hundreds of thousands, were responsible for the miserable condition of the interior of this historic shaft.

Using 108 lb. per cu. ft. of masonry, and 50 lb. per cu. ft. of timber, I figured that the foundations carried a load of nearly 2 000 tons, or about 1 350 lb. to the square foot, exclusive of the wedge of dirt which formed the mound. I estimated that I would add approximately not over 200 lb. per sq. ft. to the load, and I concluded that this was perfectly safe under the conditions found. The total load actually carried is 4 375 000 lb. or very nearly 1 500 lb. per sq. ft.

As soon as I had completed the plans for the new work, these were approved by the Secretary of War, now our respected President, W. H. Taft, and bids were invited. The contract was awarded to Mr. M. P. Doullut, a local contractor, work started about January, 1908, and was completed at the end of the year.

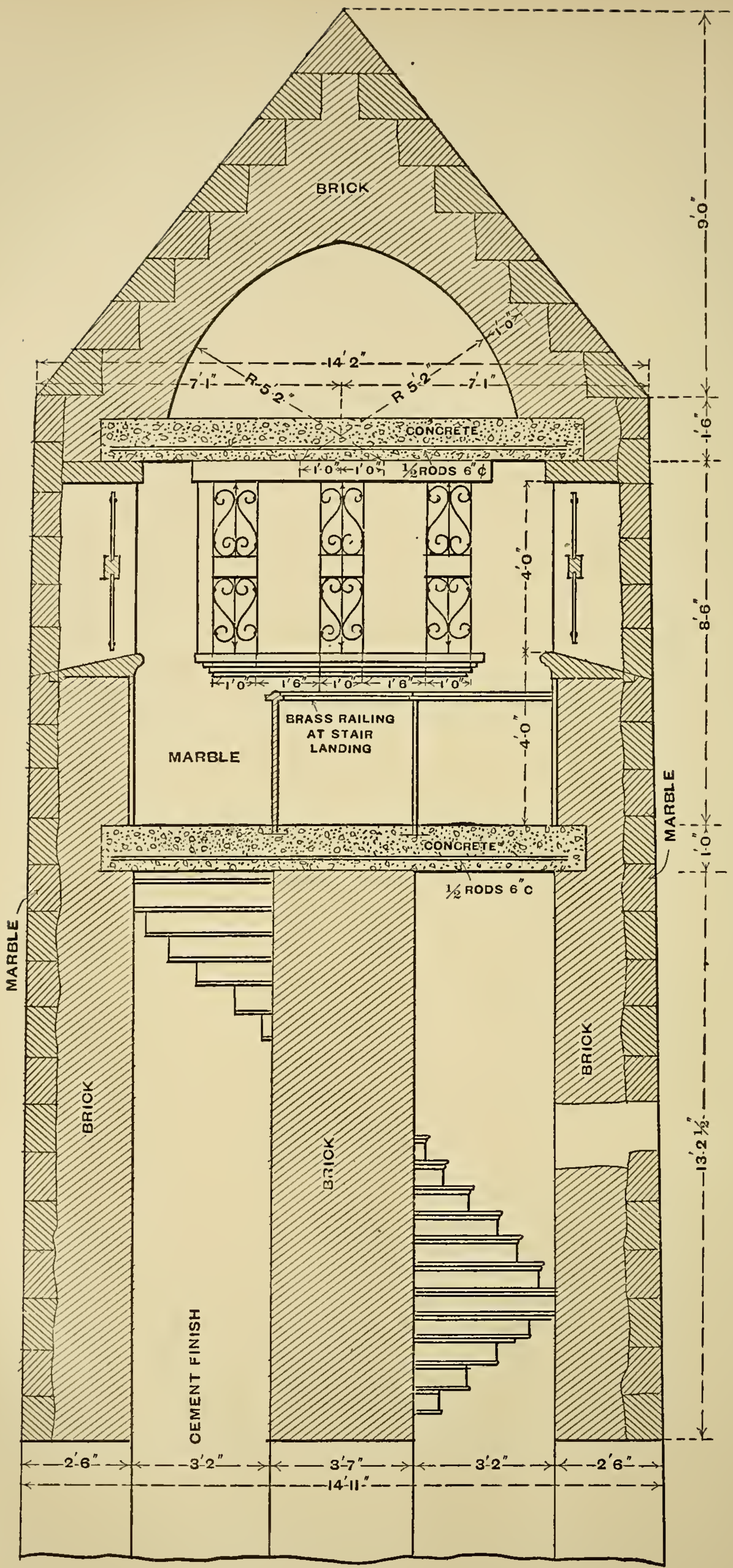
The work was accepted by the United States Government through Lieut.-Col. Lansing H. Beach, in charge of the local engineering office, and the maintenance of the monument was placed in the hands of the local chapter of the United States Daughters of 1776 and 1812, to conform to the act of Congress.

The evolution of the monument from an old brick pile to the present imposing structure is exhibited by the illustrations accompanying this paper.

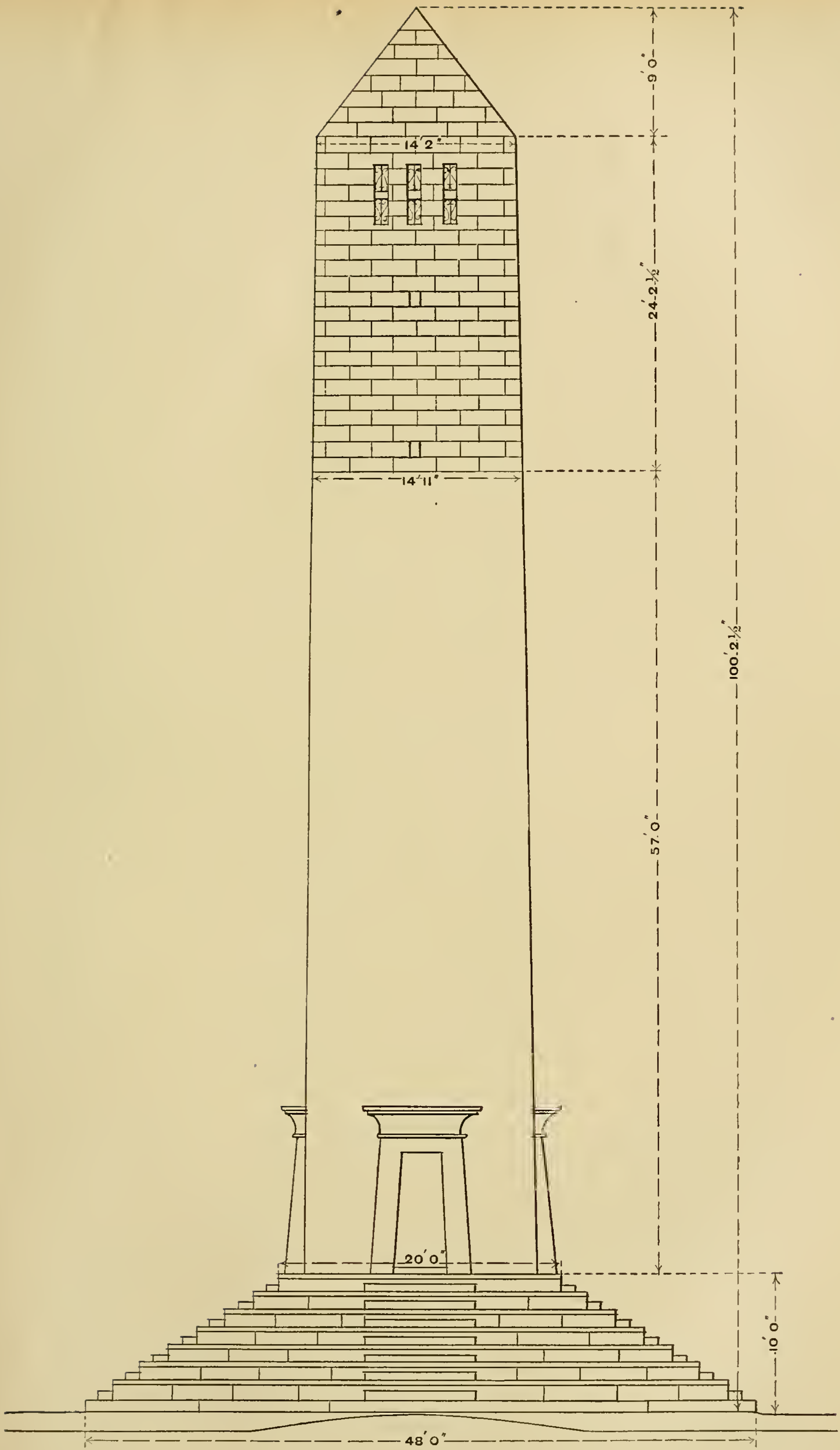
As to the total cost of the work as it stands to-day, I can only estimate it. The original contract was for \$57 000; but I suppose, as the work was only partly done, about \$40 000 is fair to assume as the original cost. This added to the last appropriation of \$25 000, which was entirely absorbed, would bring the total to \$65 000.

For a general description of the work, it is better to read a few paragraphs of the specifications (which were carried out to the letter).

18. *Character of Work.* The work to be done consists in the removal of the mound of earth covering the base of the



New Work, Section on Center Line of Shaft.



FRONT VIEW, SHOWING NEW WORK.

existing monument, the extension of the shaft on the present lines 24 ft. $2\frac{1}{2}$ in., and the covering thereof, at that point, by a pyramid 9 ft. high, making the entire structure, when completed, approximately 100 ft. above the natural level of the ground. [Actual height, 100 ft. $2\frac{1}{2}$ in.]

19. *Order of Work.* The order in which the work should be prosecuted is: (1) Completion of the shaft and pyramid; (2) cleaning and retouching the entire shaft; (3) removing the mound of earth at the base; (4) completion of the base. This order will remove any chance of tarnishing or spoiling new work, but the contractor will be allowed, with the approval of the engineer, to prosecute the work in any order which he may find suitable and to meet advantageously the time of delivery of material on the ground. [Order of work was observed.]

21. *Brickwork.* At the top of the existing brickwork a sufficient number of brick shall be removed, at intervals, to form slots so that the new and old brick work shall be well bonded. When this is done to the satisfaction of the engineer, the present brickwork will be continued, as shown on the plans, up to the base of the pyramid, care being taken to fill up with brick and mortar all rough surfaces on the rear of the marble facing so as to form a compact mass when finished. At a point in the plane immediately above the cap of the windows in the observation chamber (all as shown on drawings), and with centers as given, a cone-shaped form of timber must be built to act as a support for the brick arch which forms the pyramid. Great care will be taken in laying this brickwork to form a substantial arch, as it is essential that this work be first class in every respect.

Sufficient brick must also be removed from the base of the monument to insure a good bond between old and new work and to allow the top of the marble facing to conform to the plans. All bricks used, both in shaft and base, must be good quality, hard, sound Lake bricks. They must be properly moistened with water when laid and solidly bedded in mortar. All joints will be shove joints perfectly filled. All necessary and proper bonds, ties, anchors, rabbets, recesses, jambs and openings will be finished and completed as the work progresses to conform to the plans.

22. *Marble.* The marble used in the existing monument is what is known as the Tuckahoe marble, presumably quarried in the state of New York. It is essential that the marble to be furnished for completing the monument match as perfectly as possible the marble formerly used. Bidders must, therefore, furnish samples of the marble they propose to use and any marble which, in the opinion of the engineer, does not meet the above requirements will be rejected. [Second-hand Tuckahoe marble quarried about same time was used.]

23. *Marble Work.* The entire exterior surface of the base, shaft and pyramid will be of marble ashlar, not less than 3 and 6 in. thick, respectively, for the base and shaft as shown. The ashlar facing of the shaft will be from 3 to 5 and 8 in. thick, as it may happen in quarrying, the thin and thick courses to be placed

The Completed Monument.

alternately, so as to form a bond with the brickwork, and to be laid up battering on the face according to the drawings, the shaft being 16 ft. 8 in. wide at the base and 14 ft. 2 in. at the top. The beds of the ashlar must be all cut to a perfectly horizontal line. Every piece in each alternate course of ashlar is to be securely cramped to the brickwork with cramps 1 ft. long, $\frac{1}{4}$ by $1\frac{3}{8}$ in. flat iron bars, let into the marble 2 in. and turned on the brickwork 3 in. and covered in the marble with proper sand and cement. All of the marble ashlar for the shaft and pyramid is to be tool and tooth finished to match the present finish. The ashlar for the face of the base course, both horizontal and vertical, is to be 6 in. thick, with proper dowels and cramps, and all courses are to be laid to a perfect horizontal line. All the exposed surfaces of the marble work in the base are to be sand finished.

The present facing is to be removed as far down from the top as may be necessary to restore the facing to its proper alignment, and to permit the refilling of the joints which have been cracked and destroyed by vegetable growth. All missing or broken pieces of facing or broken corners or projections over openings are to be replaced where necessary, and the joints refilled.

24. *Marble Steps.* The exterior steps, as shown ascending the base of the monument on the four sides, are to be solid blocks of marble, 8 in. by 12 in. by 8 ft. Dowels and cramps for the steps are to be of copper, $\frac{3}{8}$ in. thick.

25. *Marble Veneer.* The four walls of the observation chamber at top of monument shall be covered with a polished marble veneer not less than 1 in. thick and properly fastened to the brickwork. The marble caps and sills for the lookouts or openings in the observation chamber shall be carried out as shown on the drawings.

Iron steps were continued to the floor of the observatory or chamber, which is lined with panels of Georgia marble, and has twelve bronze grilled openings with a glazed sash.

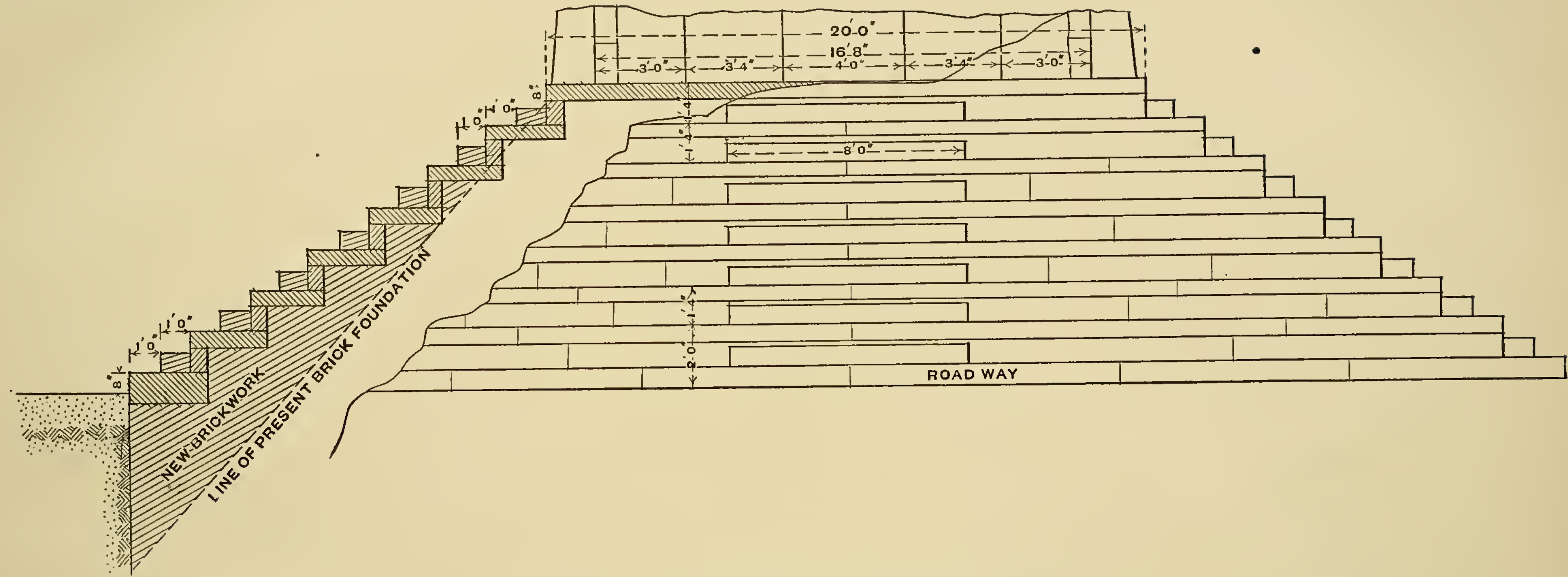
The entrance has a heavy bronze door.

A bronze tablet placed inside of the monument is inscribed as follows:

"Monument to the memory of the American soldiers who fell in the Battle of New Orleans at Chalmette, Louisiana, January 8th, 1815.

"Work begun in 1855 by Jackson Monument Association.— Monument placed in custody of United States Daughters of 1776 and 1812 on June 14th, 1894—Monument and grounds ceded unto the United States of America by the State of Louisiana on May 24th, 1907—Completed in 1908 under the provisions of Act of Congress approved March 4th, 1907."

No definite plans have as yet been worked out for improving



PART ELEVATION AND SECTION OF BASE AS ALTERED.

the surroundings and approaches to the monument. It would be proper, if land could be secured, to have a roadway about 100 ft. wide connecting the monument plot with the Chalmette Cemetery. If no land is acquired, a proper driveway lined on both sides with artificial stone walks should connect the public road with the monument; that, of course, would be on the present plot.

In closing these remarks, I will say that the work was done well, and, in my opinion, the monument, so far, is completed in a fit and appropriate way, and that it will forever be a credit, not only to those who have planned and designed it; not only to those who have generously contributed to its erection; not only to him in whose honor it was erected, the gallant and respected American, Andrew Jackson; not only to those who have lost their lives in the great battle which it commemorates; but that it will, as well, become the pride of these good ladies, who, by their indefatigable zeal, patriotism, devotion and respect for the achievements of their forefathers, succeeded in getting this great monument completed after it had been abandoned and nearly forgotten.

[NOTE. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by December 1, 1909, for publication in a subsequent number of the JOURNAL.]

DISCUSSION OF MR. FLETCHER'S PAPER, "THE FIRST INTERNATIONAL ROAD CONGRESS."

(VOL. XLII, PAGE 200, APRIL, 1909.)

MR. L. F. PATSTONE. — In reviewing the proceedings of the "First International Road Congress," held at Paris in October, 1908, it would seem that there had been too much generalization and not sufficient specific information of processes and results.

The most effective accomplishment of this Congress was the impetus it gave to a more general exchange of ideas along the various lines of road construction than has obtained heretofore and the provision for the Second Road Congress to meet at Brussels in 1910.

A few of the papers seem to disclose the proneness of their authors to get upon the house-tops and shout, "I did it," without telling how or giving the important facts in the cases. The idea seems to have been lost sight of that a congress of this nature is supposed to get down to the cold unvarnished facts and present them in a concise form from which may be obtained *Results*.

Merely to bring out a more general discussion of the progress being made in roads and pavements, the writer intends setting forth what he believes should be taken into consideration in working out standards for road construction.

The first points to be considered in determining the character of construction are, climate, character of traffic, character of soil and contour of country. Under climate should be considered the amount of rainfall or melted snow per year and the maximum and minimum periods of their occurrence. The maximum and the minimum temperature should be gone into, and the approximate periods over which they extend determined.

The character of traffic should be considered under the headings of rural, suburban and city. The number of ton miles per hour and per day, together with the maximum and the minimum loads, should be determined. The season of maximum and minimum traffic, the class and the rate of speed, together with the character of the tires, should also be determined.

The character of soil, such as imperviousness, height of ground water in relation to road foundation and minimum bearing power of the soil should be investigated.

The contour of the country, the maximum and the minimum grade and the radius of curvature in changing direction should be considered.

From the data as above outlined may be determined the thickness of the foundation, the character of the wearing surface, the cross section of the road and the method of maintenance. An important factor in determining the thickness of the foundation is the bearing power of the soil. The construction of a table having legs composed of 12 in. by 12 in. stock to be used in determining the bearing power of poorer soils will be found effective The table is to be placed over a portion of the ground previously saturated with water and then loaded with pig-iron until failure results, or a figure obtained for the minimum bearing value. With this bearing value the thickness of the road may be obtained by taking the maximum wheel load and assuming that it is carried down through the foundation at an angle of 45 degrees. If we let D equal the required depth, W the wheel-load and B the bearing power of the soil we derive, $D=\sqrt{\frac{W}{4B}}$. A safe depth for the foundation may now be found by subtracting one half of the thickness of the wearing surface from the total thickness of the road just determined.

The character of the traffic and the relative cost of available material, together with the cost of maintenance, should be carefully gone into in selecting the wearing surface. The question of sanitariness, ease of cleaning and fitness for the locality are also points that may have to be considered.

The question of the cross section depends largely on the character of the wearing surface. The crown should be such as to carry off the water without injuring the surface. It should also carry it off quickly enough to prevent the possibility of freezing before reaching the sides.

The foothold for horses and the setting of vehicles on the road are points to be kept in mind. There appears to be a tendency in working out the crowns of roads, and also pavements, to deduce the equation of some curve or to make the ordinates a certain proportion of the total rise, losing sight of the fact that the foothold for horses is a factor in determining the crown. The writer recalls an instance on a smooth pavement where the crown at the different points was made dependent on a certain proportion of the rise, and as a result the rate of rise at the sides of the street was between 5 or 6 per cent., and, as was to be expected, trouble was experienced from horses falling on this pavement.

The width of roadway and the thickness of the wearing surface are dependent on the character of the locality through which the road passes and the amount and character of traffic. For rural communities, where the traffic is at a minimum, the roadway may be only 12 ft. in width, and in communities where the traffic increases to such an extent as to occasion a great deal of passing, the width should not be less than 16.5 ft.

The character of maintenance is nearly as important as the first construction. The success or failure of any system, however, is dependent on the superintendence.

The point as to whether the money shall be raised by direct or indirect tax, or the labor performed by contract, local labor working out the taxes, or regular skilled employees, is not so important as the one of competent skilled superintendence. Standard construction, proper machinery and tools and experienced supervision are the requisites for successful roads. (Under these conditions the number of men per mile and the amount allowed per mile per year will be brought to a reasonable figure.)

The following classes of road construction appear to the writer to be fitted for the peculiar service required of them.

Road for Vehicles of Slow Speed. — Width of roadway from 12 ft. to 16.5 ft., with additional 4 ft. on each side for slope to shallow gutter. Grade from center to sides not less than 4 per cent. Sub-grade, thoroughly rolled by road roller of not less than 10 tons. Thickness of foundation dependent on bearing power of soil when saturated with water. In soils having a bearing power of 1 000 lb. the thickness of the foundation should not be less than 9 in. This thickness will gradually decrease so that a bearing power of 4 000 lb. will be sufficient to insure good results without a foundation. Upon this foundation should be laid a 3-in. course of 2½-in. stone. This course should be sprinkled and rolled at the rate of 500 sq. yd. per hour. The 3-inch top course of 1½-in. stone should then be added and should be sprinkled and rolled at the rate of 100 sq. yd. per hour. Stone dust and screenings should then be added and the surface thoroughly flushed, brooms being used to work the binder into the voids. The road should not be opened to traffic for at least five days after completion, and should be kept sprinkled for at least ten days.

It may be contended that the thickness of the foundation is excessive, but the writer has found that such a thickness is economical and that a district where the thickness of the founda-

tion has been determined from the bearing power of the soil will have good roads to show at the end of a given period, whereas at the end of the same period in a section where little or no attention has been paid to the foundation there will be nothing to show but bad roads or apologies for roads for equal expenditure.

Country Road for Vehicles of Slow and High Speed. — Width of roadway not less than 16.5 ft., with additional 4 ft. on each side for slope to shallow gutter. Foundation same as that described under "Country Road for Vehicles of Slow Speed." Upon this foundation place a 4-in. layer of broken stone of sizes ranging from 2 in. to 3 in. Roll this layer at the rate of 300 sq. yd. per hour and then flush over the surface a mixture of 2 parts coal tar, 1 part pitch and 1 part asphalt, applied at a temperature of 150 degrees fahr. and at the rate of 0.8 gal. per square yard.

Upon a platform provided for the purpose spread a layer of stone ranging from ½ in. to 1½ in. in size and coat same with a mixture of 1 part asphalt and 1 part coal tar, using at the rate of 22 gal. per cubic yard. Spread this on the previously laid portion to a depth of 3 in. and roll same until thoroughly compacted. Allow this to stand 24 hr. and then flush the surface with a mixture of 1 part asphalt, 1 part pitch and 1 part coal tar. Immediately spread a layer of clean, dry, sharp sand. Let this stand for a day and then roll. Roll the section slightly every day for a period of five days and then open to traffic.

Treatment of Existing Macadam Roads to Fit Them for Fast Moving Self-Propelled Vehicles. — Loosen up the surface of the existing macadam by using picks in the road roller wheel. After the road has been picked sufficiently, use a harrow to still further loosen the surface. The roller can be used to pull the harrow, care being taken that the chain used for hauling is of sufficient length and so connected as to prevent the necessity of the roller having to pass over the portion previously harrowed. Any soft places that may develop should be excavated and filled with broken stone. After this surface has been brought to proper cross section, flush the same with coal tar heated to 150 degrees fahr., using at the rate of ½ gal. per square yard. This material may be either spread by the use of dipper, may be flushed on from a hose attached to the heating tank or from one of the patented spraying machines. Allow the surface to stand 24 hr. and then spread a 1-in. layer of ¼ in. to ½ in. stone chips coated with a mixture of 1 part asphalt and 1 part coal tar, using at the rate of 22 gal. per cubic yard. Roll with a 10-ton roller at the rate of

300 sq. yd. per hour. Allow to stand for 24 hr. and then flush over the surface a mixture of 1 part asphalt, 1 part pitch and 1 part coal tar. Immediately spread over the surface a layer of clean, dry, sharp sand. Let this surface stand for a day and then roll. Roll slightly every day for a period of five days and then open to traffic.

In the use of coal tar, pitch and asphalt certain precautions are necessary to insure good results. Before any work is started an analysis of the material to be used should be made; in fact, as much precaution should be taken as is observed in determining the character of cement which is to be used in any large engineering construction.

Especial care should be used with the coal tar to see that the loss of volatile matter does not exceed 7 per cent. when kept at a temperature of 120 degrees for 6 hr. In heating the mixture every precaution should be taken to prevent burning. This is often one of the principal causes of failure.

In concluding, the writer wishes to suggest a few points to be taken up by the next International Road Congress.

1. Standard cross section for roads of various classes of traffic.

2. Thickness of foundation necessary for various classes of soil and traffic.

3. Specifications for coal tar, pitch and asphalt.

4. Machinery for mixing and applying bitumen.

5. General road machinery.

6. Specific data giving point by point the methods to be followed in the various types of road construction.

7. Data covering pavements for heavy traffic.

8. Include in the proceedings the question of pavements for city streets.

9. Wheel and tire ordinance.

DISCUSSION OF PAPER BY S. BENT RUSSELL, "NOTES ON CERTAIN POINTS IN THE DESIGN OF LARGE FILTRATION PLANTS."

(Volume XLII, Page 323, June, 1909.)

Mr. E. G. Manahan. — In determining the capacity of wash water devices for large mechanical filtration plants, the author neglects two essential factors. *First*, extra capacity must be provided because filters should not be washed in regular rotation at equal intervals of time, but, in order to prevent loss of filter capacity, must be washed whenever washing becomes necessary. *Second*, spare capacity must be provided, not only for times of cleaning and minor repairs of the pumps, but also for times when a pumping unit must remain entirely out of service for repairs for a number of days. Neglect of these factors means failure.

Furthermore, the author's illustration, in which he assumes 3 gal. as the number of gallons of wash water required per 100 gal. of water filtered with worst water, is misleading. Three gallons is about an average figure. The maximum should be assumed at not less than 5 gal.

The author apparently criticises the wash water capacity of the Cincinnati plant. After noting that the capacity of the pumps is only 2 500 gal. per minute each, and making proper assumptions and allowances, as above, it is, however, seen that the Cincinnati pumps are too small rather than too large. Space and connections are provided at Cincinnati for the installation of an extra pump if needed in the future.

The additional flexibility and certainty of operation obtained by providing a wash water reservoir of a capacity greater than one washing in most instances justifies its extra cost, which is an extremely small percentage of the cost of the whole plant. Where, as at Cincinnati, the reservoir performs other important functions besides the storage of wash water, the provision for a storage only equal to or less than the volume of one washing, as the author seems to recommend, would be extremely inadvisable.

ASSOCIATION OF ENGINEERING SOCIETIES.

Articles of Association Adopted December 4, 1880.

For the purpose of securing the benefits of closer union and the advancement of mutual interests, the engineering societies and clubs hereunto subscribing have agreed to the following Articles of Association.

ARTICLE I.

NAME AND OBJECT.

The name of this Association shall be the "Association of Engineering Societies." Its primary object shall be to secure a joint publication of the papers and transactions of the participating societies.

ARTICLE II.

ORGANIZATION.

Section 1. The affairs of the Association shall be conducted by a Board of Managers under such rules and by-laws as they may determine, subject to the specific conditions of these articles. The Board shall consist of one representative from each society of one hundred members or less, with one additional representative from each additional one hundred members, or fraction thereof over fifty. The members of the Board shall be appointed as each society shall decide, and shall hold office until their successors are chosen.

Sect. 2. The officers of the Board shall be a Chairman and Secretary, the latter of whom may or may not be himself a member of the Board.

ARTICLE III.

DUTIES OF OFFICERS.

Section 1. The Chairman, in addition to his ordinary duties shall countersign all bills and vouchers before payment and present an annual report of the transactions of the Board; which report, together with a synopsis of the other general transactions of the Board of interest to members, shall be published in the Journal of the Association.

Sect. 2. The Secretary shall be the active business agent of the Board and shall be appointed and removed at its pleasure. He shall receive a compensation for his services to be fixed from time to time by a two-thirds vote. He shall receive and take care of all manuscript copy and prepare it for the press, and attend to the forwarding of proof-sheets and the proper printing and mailing of the publications. He shall have power, with the approval of any one member of the Board, to return manuscript to the author for correction if in bad condition, illegible or otherwise conspicuously deficient or unfit for publication. He shall certify to the correctness of all bills before transmitting them to the Chairman for countersignature. He shall receive all fees and moneys paid to the Association and hold the same under such rules as the Board shall prescribe.

ARTICLE IV.

PUBLICATIONS.

SECTION 1. Each society shall decide for itself what papers and transactions of its own it desires to have published and shall forward the same to the Secretary.

SECT. 2. Each society shall notify the Secretary of the minimum number of copies of the joint publications which it desires to receive, and shall furnish a mailing-list for the same from time to time. Copies ordered by any society may be used as it shall see fit. Payments by each society shall, in general, be in proportion to the number of copies ordered, subject to such modification of the same as the Board of Managers may decide by a two-thirds vote to be more equitable. Assessments shall be quarterly in advance, or otherwise, as directed by the Board.

SECT. 3. The publications of the Association shall be open to public subscription and sale, and advertisements of an appropriate character shall be received under regulations to be fixed by the Board.

SECT. 4. The Board shall have authority to print with the joint publications such abstracts and translations from scientific and professional journals and society transactions as may be deemed of general interest and value.

ARTICLE V.

CONDITIONS OF PARTICIPATION.

SECTION 1. Any society of engineers may become a member of this Association by a majority vote of the Board of Managers, upon payment to the Secretary of an entrance fee of fifty cents for each active member, and certifying that these Articles of Association have been duly accepted by it. Other technical organizations may be admitted by a two-thirds vote of the Board, and payment and subscription as above.

SECT. 2. Any society may withdraw from this Association at the end of any fiscal year by giving three months' notice of such intention, and shall then be entitled to its fair proportion of any surplus in the treasury, or be responsible for its fair proportion of any deficit.

SECT. 3. Any society may, at the pleasure of the Board, be excluded from this Association for non-payment of dues after thirty days' notice from the Secretary that such payment is due.

ARTICLE VI.

AMENDMENTS.

These articles may be amended by a majority vote of the Board of Managers, and subsquent approval by two thirds of the participating societies.

ARTICLE VII.

TIME OF GOING INTO EFFECT.

These articles shall go into effect whenever they shall have been ratified by three societies, and members of the Board of Managers appointed. The Board shall then proceed to organize, and the entrance fee of fifty cents per member shall then become payable.

RULES OF THE BOARD OF MANAGERS OF THE ASSOCIATION OF ENGINEERING SOCIETIES, ADOPTED MARCH 1, 1905, AND AMENDED AUGUST 18, 1906.

SOCIETIES.

ASSESSMENTS.

1. Assessment bills shall be rendered to the societies quarterly after the mailing of the JOURNALS for March, June, September and December.

2. Each society shall be assessed in proportion to the number of names upon its mailing list at the time when the assessment is made, provided that no society shall be assessed for less than twenty (20) copies of the JOURNAL, and provided that no society shall be assessed for less than fifty (50) per centum of its membership at the time when the assessment is made.

3. Each society shall be entitled to receive, gratis, five copies of each issue of the JOURNAL for each of its representatives on the Board of Managers of the Association.

DELINQUENT SOCIETIES.

4. Any society which shall remain indebted to the Association for a sum exceeding two dollars per member for more than ninety days after mailing of notice by the Secretary, shall be suspended from the privileges of the Association until the cause be removed, provided that this rule shall not apply to indebtedness on account of advertisements secured by the society for the JOURNAL.

GOVERNMENT.

5. A meeting of the Board of Managers may be called by the Chairman at any time, and shall be called by the Chairman or Secretary upon the written request of any three members of the Board, and such call shall give not less than three weeks' notice of said meeting.

6. At any meeting of the Board of Managers, duly called as provided in Rule 5, one fourth of the whole number of members (including the Chairman) shall constitute a quorum, provided that not less than three of the constituent societies be represented at such meeting.

7. Motions for letter ballot shall be made and seconded and then forwarded by the Chairman to each member of the Board for discussion.

8. All letter ballots shall close four weeks after the date of mailing call, by the Chairman, for vote.

9. Rules of the Board of Managers may be amended at any time by a majority vote of the Board, as ascertained by letter ballot.

OFFICERS.

10. The term of office of the Chairman and that of the Secretary shall be two (2) years, and shall begin on January 1 of the even years, but they shall remain in office till their successors are chosen.

11. The election of officers shall occur at any time at a called meeting of the Board, or by letter ballot between October 1 and December 1 of the odd years.

12. If the election is by letter ballot, the Chairman shall, through the Secretary, give notice of such election prior to October 10 of each odd year, and shall also give notice, at the same time, of the appointment of two tellers in one city, members but not officers of the Board, to whom

the votes shall be mailed. These tellers shall open the ballots on November 1, and report the result to the Chairman of the Board. If no one has received a majority of the votes cast for either office, the Chairman shall order a new ballot, similar to the first, but limiting the names voted for to the two receiving the highest numbers of votes for that office on the first ballot. The tellers shall open the second ballot on December 1, and report as before. The Chairman shall then announce the result of the ballot to all the members, and the new officers shall act from the beginning of the following calendar year. In the event of the second ballot resulting in a tie, the Chairman shall select between the two candidates by lot.

13. Vacancies in the offices of the Board may be filled at any time, either by a meeting of the Board or by letter ballot. In case of a vacancy occurring, the remaining officer shall discharge the duties of both till the vacancy is duly filled.

14. The Secretary shall receive a salary of nine hundred dollars ($900) per annum.

ACCOUNTS.

Audit.

15. Prior to the close of each odd year, the Chairman shall appoint from the members of the Board of Managers, two auditors to examine and report upon the accounts of the Secretary.

JOURNAL.

Contents.

16. The matter published in the Journal shall be restricted to:

(A) Monthly.

1. Papers submitted by the societies for publication, including presidential addresses and memoirs of deceased members.
2. Proceedings of meetings of the societies.
3. Lists of officers of the societies.
4. List of members of Board of Managers.
5. Advertisements.

(B) Annually.

1. Annual report of Chairman and of Secretary of Board of Managers.
2. Articles of Association, Rules of Board and rulings of Chairman.

(C) Biennially.

Report of Auditors.

Conduct.

17. Arrangements with printers and illustrators shall be made by the Secretary, subject to the approval of the Board of Managers.

18. The arrangement of matter, the selection and manner of reproducing illustrations and all other matters relating to typography, shall be decided by the Secretary with the approval of the Chairman.

19. The Secretary shall insert in each issue of the Journal the following: Editors reprinting articles from this Journal are requested to credit the author, the Journal of the Association and the Society before which such articles were read.

20. Authors of papers appearing in the Journal shall have appended to their names only the words, "Member of................Society."

Reprints.

21. Reprints of papers appearing in the Journal shall be made, when requested for the account of the societies submitting the papers for publication.

22. Each author shall be entitled to receive gratis 50 reprints of his paper, with its discussion and illustrations, on condition that application for such reprints is made by the author, through the secretary of the society presenting the paper for publication, previous to the printing of the paper for the Journal.

23. The rates of charges to the societies for other reprints shall be adjusted by the Chairman and Secretary.

Illustrations.

24. Cuts, published with linear scales, shall bear metric scales, unless objection is made by the authors.

Advertisements.

25. The procuring and selection of advertisements, including the fixing of rate of commissions, shall be subject to the control of the Chairman and Secretary.

26. Advertisements procured for the Journal by the societies composing the Association shall be charged to those societies, less 90 per cent commission.

Subscriptions.

27. The rate of subscriptions to the Journal shall be $3.00 per annum.

28. Dealers shall be allowed on subscriptions a discount of 50 cents per annum.

29. Educational and charitable institutions may be furnished with the Journal at $1.50 per annum, subject to the approval of the Chairman and Secretary.

Exchanges.

30. Exchanges with other periodicals may be made subject to the approval of the Chairman and Secretary.

Sales and Gratis Copies.

31. The price of single copies of the Journal shall be 30 cents, less a discount of 5 cents to dealers.

32. Members of the societies belonging to the Association shall be entitled to receive copies of the Journal at 20 cents each. This rule is subject to amendment by the Chairman and Secretary in the case of scarce or surplus numbers, or of sets of back numbers.

33. The Secretary is authorized to furnish to the author of any paper to whom reprints are not given, and to each of those taking prominent part in the discussion, five gratis copies of the Journal containing such paper, and, at 15 cents each, additional copies of the issue of the Journal containing such paper, provided due notice be given in advance, stating the number of such extra copies wanted.

FINAL CONTROL BY BOARD.

34. The exercise of any discretions herein delegated to the Chairman and Secretary shall be subject to the final control of the Board of Managers.

ASSOCIATION OF ENGINEERING SOCIETIES.

Organized 1881.

VOL. XLIII. OCTOBER, 1909. NO. 4.

FILING AND INDEXING SYSTEM OF BOARD OF WATER SUPPLY OF THE CITY OF NEW YORK.

BY ALFRED D. FLINN, MEMBER BOSTON SOCIETY OF CIVIL ENGINEERS.

[Read before the Society, January 27, 1909.]

THE Secretary has requested me to put on record in the JOURNAL a description of the system of filing and indexing devised for the large and scattered engineer organization of the Board of Water Supply of the City of New York. In response, I have compiled a number of extracts from the regulations prepared under my immediate direction. These have been prefaced by an outline of the project and the organization so that the system may be intelligible.

To supplement the outgrown water supplies of the various boroughs of Greater New York, the Board of Water Supply was created by legislative enactment in June, 1905. This board has determined to develop successively four considerable watersheds in the Catskill Mountains and the ground waters of Suffolk County in eastern Long Island. From City Hall, New York, to the most distant proposed Catskill Mountain reservoir is 130 miles in an air line, and to the extremity of the Suffolk County system, 75 miles. Esopus watershed, the first to be developed, will have one impounding reservoir of 128 000 000 000 gal. capacity, sufficient to store also part of the waters of Schoharie Creek, to be brought in by a 10-mile tunnel through the mountain range. This reservoir, the Ashokan, is 90 miles from New York and 590 ft. above mean tide. From it, Catskill aqueduct, of 500-000 000 gal. safe average daily capacity, will convey the water to

Hill View reservoir, a 900 000 000 gal. equalizing reservoir at elevation 295, on the northerly boundary of the city. This aqueduct comprises several types of construction; Cut-and-cover, grade tunnel, pressure tunnel, reinforced concrete pipes, steel pipes lined with mortar and jacketed in concrete, and reinforced cut-and-cover under slight pressure. Its total length will be 92 miles, crossing the Hudson River, several broad valleys below gradient, and piercing several ranges of hills and mountains. When needed, branch aqueducts will bring the water from the Rondout and Catskill creeks. On the line of the Catskill aqueduct, 30 miles from New York, Kensico storage and distribution reservoir of 40 000 000 000 gal. capacity will be constructed. It will serve the double purpose of permitting repairs and inspection of the Catskill aqueduct between this place and Ashokan reservoir almost as well as a duplicate aqueduct, and of maintaining relatively near the city a reserve storage of about two months' supply.

At Kensico and Ashokan reservoirs there will be extensive aëration fountains, through which the water will pass when drawn into the aqueduct. At East View, 3 miles from Kensico reservoir, a large filter plant is to be built. Venturi meters, with 7 ft. 9 in. throats, are to be built into the Catskill aqueduct at three places, and current-meter gaging chambers will also be provided. Drainage shafts and unwatering equipments are to be adjuncts of the deep pressure tunnel siphons. From Hill View reservoir, a pressure tunnel deep in the rock will extend under the borough of the Bronx, Harlem River, Manhattan Island and East River to Brooklyn, whence large pipe lines will continue to Queens Borough and beneath the Narrows to Staten Island. At shafts along this tunnel connections will be made with the trunk mains of the distributing pipe system.

In Suffolk County the underground water is to be gotten by means of deep wells, probably of the California stovepipe variety. These wells will be spaced along a right of way 1 000 ft. wide, approximately parallel to the south shore of the island and about 2 to 3 miles back from the ocean. Branches will extend into several valleys. Small pumping outfits will raise the water from the wells into a 250 000 000-gal. concrete aqueduct, which will convey the water by gravity across Nassau County into the heart of Brooklyn. Here a large pumping station will elevate the water to the distributing level.

For the ultimate completion of these two projects the total cost may be roughly estimated at upwards of $200 000 000,

but this expenditure will be spread over many years, and the works will probably be completed by the following generation.

A little reflection will cause one to realize that a water-works project of such magnitude, with so diverse elements, will make more or less extensive demands upon nearly all branches of engineering and seek aid from several other professions. A great many arts and crafts will be laid under tribute. The complexity and volume of the materials to be filed and indexed now becomes apparent. Because of the geographical extent of the works, a large number of offices is needed during the years of construction. Further complication is caused by the size of the organization and the wide separation of its several units. Besides all this, the system must be devised and perfected as a minor detail, while the organization and works are being rapidly developed.

The Board of Water Supply of the City of New York consists of three commissioners appointed by the mayor. Its forces are divided into an Administration Bureau and an Engineering Bureau. The Administration Bureau is under the general supervision of the secretary, and at the head of the Engineering Bureau is the chief engineer. There are three regular consulting engineers and several experts who advise along special lines.

The Administration Bureau has charge of official records, accounts, payrolls, the purchase of equipment and supplies, and of general executive matters. Its work is divided among an auditor, a head bookkeeper, a chief clerk and a paymaster. All legal affairs come to this bureau, and, so far as necessary, are referred to the corporation counsel or to special counsel. Real estate transactions and the settlement of all claims relating to real and personal property acquired by the board, and all claims for damages not disposed of by appraisal commissions are handled by a special department of this bureau.

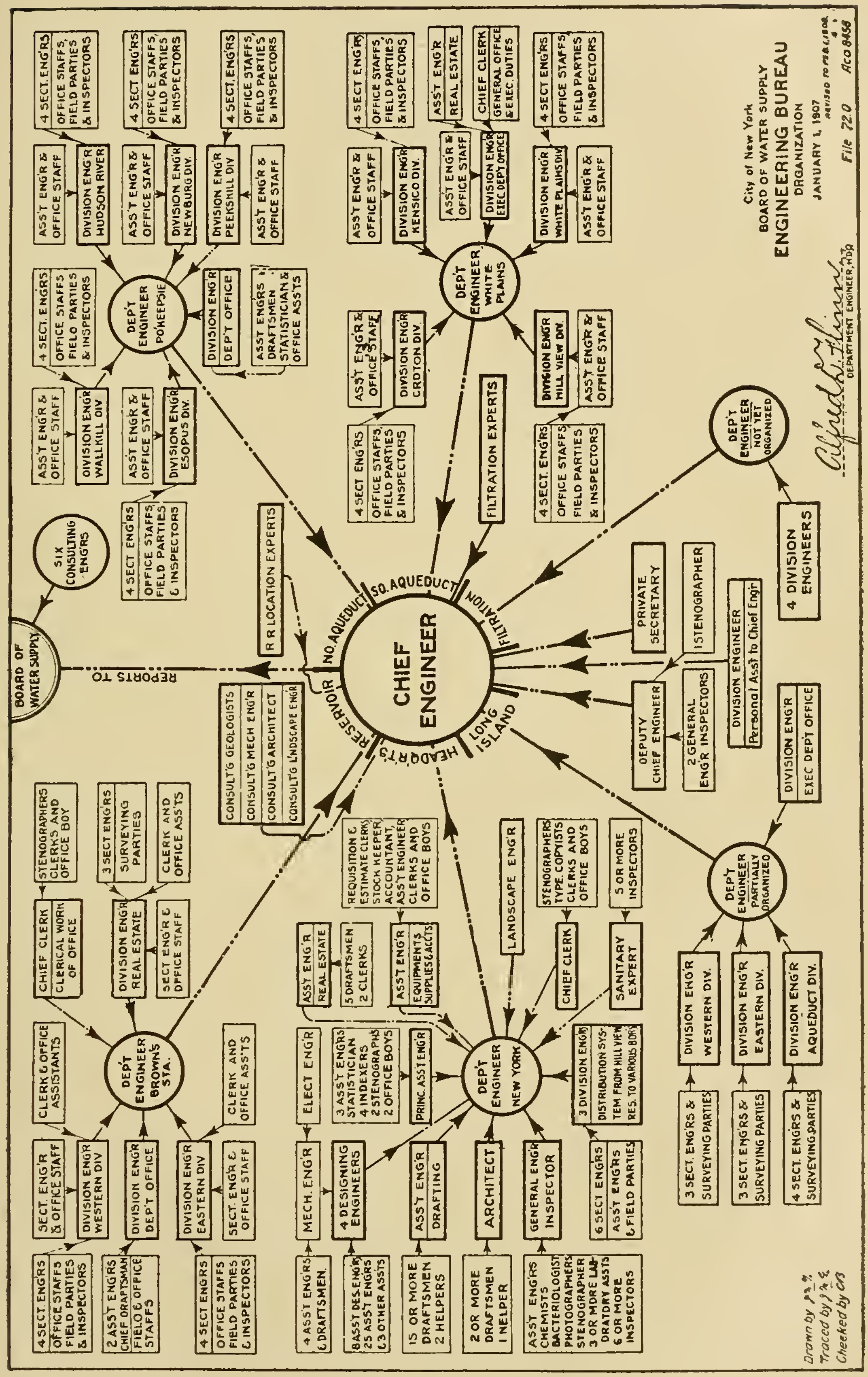
The Engineering Bureau is composed of six departments, determined by the character and location of different parts of the work, namely: Headquarters, Reservoir, Northern Aqueduct, Southern Aqueduct, Filtration, and Long Island. The departments are divided into divisions, and the divisions are subdivided into sections. This bureau has charge of all engineering matters, including surveys of all kinds, designs and specifications, superintendence of construction and inspection of materials. Communications from the Engineering Bureau to the Administration Bureau pass through the hands of the chief engineer, deputy chief engineer or the department engineer of

Headquarters Department. The organization of the Engineering Bureau is shown by the accompanying diagram, which has been modified as the work developed. It is probable that the filtration plant will be constructed by the Southern Aqueduct department, since the site is within the territory of that department and the preliminary surveys have been made by it. Instead of a filtration department, therefore, a City Aqueduct department may be organized to relieve Headquarters of part of the work connected with the delivery or distribution of the new water to the various boroughs of the city; the Distribution division of Headquarters department now has this work in hand and will, doubtless, be the nucleus of the new department organization.

The filing and indexing system described in this paper was not designed for universal application, nor even for general engineering use, but for the extensive and comprehensive system of water works for New York City being constructed by the Board of Water Supply. However, the principles and many of the details may be applicable in other large offices and even in small ones. The system is an appropriation and adaptation, to a large degree, and is the product of the combined efforts of many employees of the board. It is not perfect, but is proving satisfactory and is so flexible that it can be modified to meet varying needs or correct faults as discovered.

Better results could be attained if the men having the broadest and deepest knowledge of the works and organization could personally supervise filing and indexing. But these men are the chief engineer, heads of departments and divisions, and have much more important duties. Furthermore, filing and indexing must be done at least cost, and, consequently, by persons of less earning capacity. One of the most annoying difficulties in maintaining a large filing and indexing system is that those having sufficient ability to do the work will usually have other ambitions, soon outgrow such positions and move on. In large organizations with many high-salaried men, the economy secured by efficient and rapid handling of documents justifies somewhat higher remuneration for the man in charge than has commonly been paid. Furthermore, those in charge of filing and indexing should be given definite opportunities to keep familiar with the works and organization.

Memory is an indispensable adjunct to any filing and indexing system, no matter how complete. Nothing will more acceptably enhance the value of the service of the attendants. From the highest official down, the more accurately the few simple


City of New York
BOARD OF WATER SUPPLY
ENGINEERING BUREAU
ORGANIZATION
JANUARY 1, 1907
File 72.0
CHIEF ENGINEER
BOARD OF WATER SUPPLY
REPORTS TO
SIX CONSULTING ENG'RS
NO. AQUEDUCT
SO. AQUEDUCT
FILTRATION
LONG ISLAND
HEADQ'R'S
RESERVOIR
DEP'T ENGINEER POKEEPSIE
DEP'T ENGINEER WHITE PLAINS
DEP'T ENGINEER NOT YET ORGANIZED
DEP'T ENGINEER PARTIALLY ORGANIZED
DEP'T ENGINEER NEW YORK
DEP'T ENGINEER BROWN'S STA.
DIVISION ENG'R HUDSON RIVER
DIVISION ENG'R NEWBURG DIV.
DIVISION ENG'R PEEKSKILL DIV
DIVISION ENG'R WALLKILL DIV
DIVISION ENG'R ESOPUS DIV.
DIVISION ENG'R DEP'T OFFICE
DIVISION ENG'R KENSICO DIV.
DIVISION ENG'R EXEC DEP'T OFFICE
DIVISION ENG'R WHITE PLAINS DIV
DIVISION ENG'R CROTON DIV.
DIVISION ENG'R HILL VIEW DIV.
4 SECT. ENG'RS OFFICE STAFFS FIELD PARTIES & INSPECTORS
ASS'T ENG'R & OFFICE STAFF
ASS'T ENG'RS DRAFTSMEN STATISTICIAN & OFFICE ASS'TS
ASS'T ENG'R REAL ESTATE
CHIEF CLERK GENERAL OFFICE & EXEC. DUTIES
FILTRATION EXPERTS
R R LOCATION EXPERTS
PRIVATE SECRETARY
1 STENOGRAPHER
DIVISION ENGINEER Personal Ass't to Chief Eng'r
DEPUTY CHIEF ENGINEER
2 GENERAL ENG'R INSPECTORS
4 DIVISION ENGINEERS
DIVISION ENG'R EXEC DEP'T OFFICE
DIVISION ENG'R WESTERN DIV.
DIVISION ENG'R EASTERN DIV.
DIVISION ENG'R AQUEDUCT DIV.
3 SECT. ENG'RS & SURVEYING PARTIES
4 SECT. ENG'RS & SURVEYING PARTIES
CONSULT'G GEOLOGISTS
CONSULT'G MECH ENG'R
CONSULT'G ARCHITECT
CONSULT'G LANDSCAPE ENG'R
STENOGRAPHERS CLERKS AND OFFICE BOY
CHIEF CLERK CLERICAL WORK OF OFFICE
3 SECT ENG'RS SURVEYING PARTIES
CLERK AND OFFICE ASS'TS
DIVISION ENG'R REAL ESTATE
SECT ENG'R & OFFICE STAFF
CLERK & OFFICE ASSISTANTS
SECT. ENG'R & OFFICE STAFF
DIVISION ENG'R WESTERN DIV
DIVISION ENG'R DEP'T OFFICE
DIVISION ENG'R EASTERN DIV
4 SECT. ENG'RS OFFICE STAFFS FIELD PARTIES & INSPECTORS
2 ASS'T ENG'RS CHIEF DRAFTSMAN FIELD & OFFICE STAFFS
REQUISITION & ESTIMATE CLERKS STOCK KEEPER ACCOUNTANT, ASS'T ENGINEER CLERKS AND OFFICE BOYS
ASS'T ENG'R REAL ESTATE
5 DRAFTSMEN 2 CLERKS
ASS'T ENG'R EQUIPMENTS SUPPLIES & ACC'TS
LANDSCAPE ENG'R
STENOGRAPHERS TYPE COPYISTS CLERKS AND OFFICE BOYS
CHIEF CLERK
5 OR MORE INSPECTORS
SANITARY EXPERT
ELECT ENG'R
3 ASS'T ENG'RS STATISTICIAN 4 INDEXERS 2 STENOGRAPHS 2 OFFICE BOYS
PRINC. ASS'T ENG'R
3 DIVISION ENG'RS DISTRIBUTION SYSTEM FROM HILL VIEW RES. TO VARIOUS BOR'S
MECH. ENG'R
4 DESIGNING ENGINEERS
ASS'T ENG'R DRAFTING
ARCHITECT
GENERAL ENG'R INSPECTOR
6 SECT ENG'RS ASS'T ENG'RS & FIELD PARTIES
4 ASS'T ENG'RS & DRAFTSMEN
8 ASS'T DESIGNERS 25 ASS'T ENG'RS & 3 OTHER ASS'TS
15 OR MORE DRAFTSMEN 2 HELPERS
2 OR MORE DRAFTSMEN 1 HELPER
ASS'T ENG'RS CHEMISTS BACTERIOLOGIST PHOTOGRAPHERS STENOGRAPHER 3 OR MORE LABORATORY ASS'TS 6 OR MORE INSPECTORS
DEPARTMENT ENGINEER
Drawn by
Traced by
Checked by

requirements of the system are remembered and observed, and the more accurately the persons desiring documents from the files recollect and describe what is desired, the smoother will be the working of the system.

Filing and Indexing in General.

Filing is the systematic putting away of papers, drawings, photographs or books. An index is a means for pointing out where things are to be found; specifically it is a guide to a file.

It is to be desired that files be arranged so naturally and logically and be so well labeled that documents can be found with the minimum use of the index and the index be simple. Its simplicity should make the method readily comprehensible and enable one who enters the index by any one of several probable keys to find quickly and surely what he seeks.

The index should have plenty of helpful guide or partition cards. Colors can be used advantageously to distinguish different kinds of cards in one index. Drawers or trays containing the cards should be plainly labeled.

Cross-reference cards should be made for a sufficient number of words under which a person may look for any subject to insure his finding the desired paper, drawing, photograph or book; but it is frequently better to let a person try two or three times than to write an excessive number of cross-reference cards for synonymous words. Do not increase the bulk of the index by useless cards.

Everything to be filed or to be returned to the files must be put in receptacles provided for the purpose. *Only designated file keepers* are to be allowed to put anything into or return anything to any file. Otherwise things are sure to be misplaced. Anything taken from a file, bookcase or plan case must be accounted for at the time and must be returned as promptly as possible. Only authorized persons shall have access, directly or indirectly, to the official files.

Any system must work well or it will fall into disfavor and soon go to pieces.

When inquiry is made for a paper, and several in the filing group would answer the description, instead of taking time and causing the inquirer the annoyance of getting so minute a description as to distinguish the exact paper wanted, the file clerk should at once send the group of papers from which the inquirer can quickly select the one desired.

One important purpose of a filing and indexing system is to avoid the wasteful repetition of researches and computations of

more or less general character by preserving data once accumulated so as to be readily used again.

Filing and indexing are much simplified by preparing the materials to be filed with due regard to the system. Documents prepared within the organization should be thoroughly controlled in this respect. Documents received from outsiders can also be automatically molded to some degree by skill and forethought in preparing the system, especially documents from parties with whom continued relations are maintained, — contractors, for example. All indexing is based upon the subject list described below.

Preliminary, therefore, to directions for filing and indexing, are instructions to those who write letters and reports and make drawings, and who receive documents of all kinds. These instructions may be epitomized as follows:

Letter Writing.

Write concisely. Deal with one subject only in each letter. Do not write unnecessary letters. Date each letter. Write the subject in the place provided. Place initials of stenographer in upper left corner, also name of dictator if he is other than the party who is to sign the letter.

Standard Sizes.

Standard sizes for stationery, drawings, etc., have been established for universal use. Departure from standards may be made only by permission from Headquarters office, and for sufficient reason. Papers not of standard size should, if possible, be cut or folded to a standard size for filing; if too small, they may be mounted on standard sheets. Distinctive colors are used for stationery of the several departments, in harmony with the colors used for their indexing and filing.

Size.	Description.
3 in. by 5 in.	— Index cards, memoranda, reference lists on cards.
5 in. by 8 in.	— Field notes, record cards, printed specifications,* and many printed forms and pamphlets for field pocket use.
5 in. by 15 in., 22 in., and 29 in.,	allowing for punching for rings in note cover; and
8 in. by 10 in., 15 in., 20 in., 25 in.,	approximately, *to be folded to* 5 in. by 8 in., for diagrams, tables and drawings to be used in field note covers or otherwise with 5 in. by 8 in. papers.

* Type pages are same size for all contracts, including specifications; the 5 in. by 8 in. pamphlets have much narrower margins.

Size.	Description.
6 in. by 9 in.	Printed reports and other books or pamphlets.
8½ in. by 11 in.	Letters, computations, official photograph mounts, many printed forms, and most contract pamphlets.*
8½ in. by 14 in.	Traverse sheets, estimates for contract payments, expense accounts, leases and legal forms.
11 in. by 8½ in., 13 in. and 18 in.	Sketches, diagrams, tables and small drawings to accompany computations, letters or reports. (The 13-in. and 18-in. sheets are folded to 8½ in.)
14 in. by 17 in.	Payrolls. (Size prescribed by city comptroller.)
26 in. by 40 in, 20 in. by 29 in., 14½ in. by 20 in.	Drawings of all kinds. It is intended that by far the greater number of contract and working drawings shall be 20 in. by 29 in. Real estate and topographical maps will be mostly 26 in. by 40 in.
19 in. by 24 in.	Green cross-section sheets to be used for estimates and other purposes.

Instructions to Stenographers.

Leave a margin an inch wide at the left side of all papers. This will permit binding or placing in note covers if desired. Use paper of standard size, 8½ in. by 11 in.

The person dictating a letter must give the stenographer the subject (not necessarily taken from the subject list) to be placed at the head of the letter. The stenographer must see that this is done. The name of a person or place, or other explanatory words, may be written after a general subject to indicate to what person or place the letter refers and aid in cross-referencing. The original of each letter must be written in copying ink. For the reference files, carbon copies are to be made of all letters, reports, etc., which it is necessary to file in the office where they originate. All letters going out of any department office are to be copied (carbon) on green paper. Weekly reports, communications from the chief engineer to the board, and similar documents are to be copied (carbon) on white paper. Correspondence between offices in one building is not carbon copied.

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* Type pages are same size for all contracts, including specifications; the 5 in. by 8 in. pamphlets have much narrower margins.

In writing letters, both sides of the copy paper are to be used. After the first sheet of the letter has been written, using one side of the copy paper, this should be turned so that the second sheet of the letter can be copied on the other side. Subsequent sheets are to be copied in like manner. Space in the files is thus economized. This will apply only to green carbons.

In addition to the above reference copy, tissue copies of all letters and reports are to be made, preferably on a roller copier, such as manufactured by the Library Bureau or by Yawman & Erbe. Tissues of each day should be cut the following morning and preserved as a *continuous* roll, these rolls being kept in chronological order in suitable filing cases, plainly labeled. Tissues are not intended for ordinary reference, but as a safeguard.

Some letters are written in the New York office of the Engineering Bureau which require the signature of a commissioner or the secretary. Of such a letter a green copy should be made for the files of the Engineering Bureau besides the white copy for the board's files. After the letter has been signed, a tissue copy should be taken.

Handling Mail — General.

All official mail must be received, opened, stamped and distributed by the file clerk in all offices of sufficient size to need such services. Official mail includes all letters, reports, drawings, blue prints, books, catalogues and all packages and documents which originate in or are received at any board office, addressed to any employee of the board by his civil service or office title.

Each letter, after being opened, must be stamped by the file clerk with such dating stamp as may be provided.

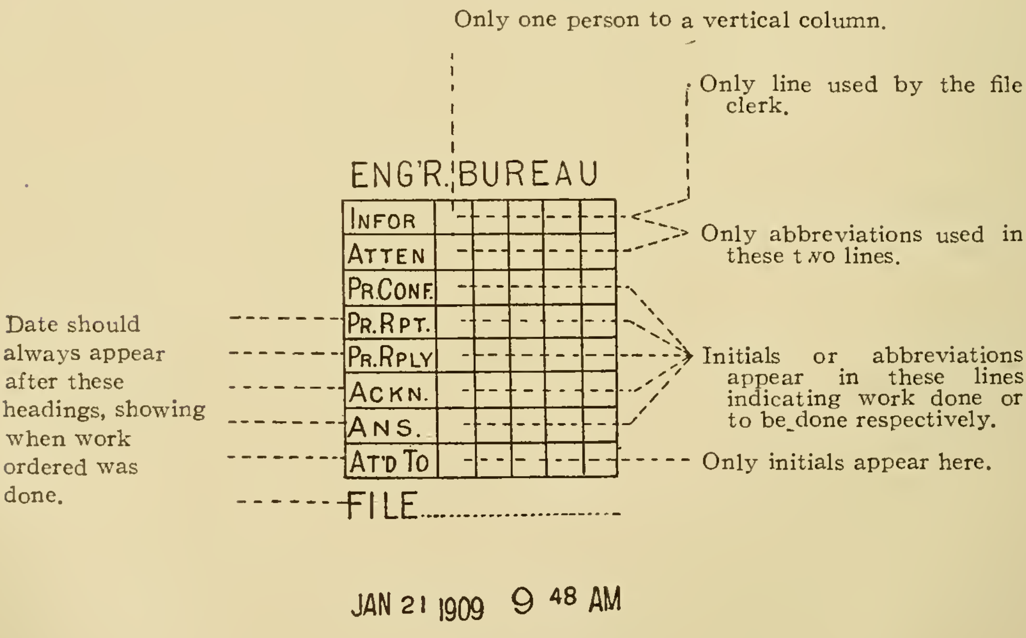
If a stamp of the appropriate kind is used, the number of the folder in which the letter is to be filed must be written after FILE NO., and in the first square after REF'D must be written the first two letters of the last name of the person to whom the letter is to be referred. When this person is through with it, he must put the initial of his last name in the square after AT'D TO, under the abbreviation of his name. In the second square after REF'D the first person may write the first two letters of the last name of any person to whom he wishes to refer the matter. The second person, after handling the letter, must put his last initial in the square after AT'D TO, under the abbreviation of his name. He can refer it to a third person and so on until the matter has been completely attended to.

When placing his initial in the space after AT'D TO and referring a letter to another person, one should be careful to indicate by pencil note on the margin what he has attended to or what remains to be attended to by the person to whom the letter is referred. If a person wishes a letter returned to him after having referred it to another, he should refrain from putting his initial in the square after AT'D TO and place a √ mark above the abbreviation of his name. The letter must then be returned to him before it is filed. When the last person who is to attend to the matter in the letter shall have finished with it, he shall sign or stamp all his initials after READY TO FILE. The letter should then be placed in a basket for filing.

Papers originating in the Engineering Bureau, or received by it, should not go to the commissioners until they have been examined by the chief engineer or by a properly authorized officer of the Engineering Bureau.

Handling Mail — Headquarters.

In Headquarters, the stamp shown below is used:



The Time Stamp.

Each letter after being opened shall be stamped on its face by the file clerk, as shown herewith, recorded, and then referred to the person concerned by placing the *abbreviation* of his name in the first vertical column of the time stamp opposite INFOR. *This is the only line of the time stamp to be used by the file clerk.*

With the relatively large mail handled in Headquarters office, it has been found convenient to assort the incoming mail

alphabetically each morning, according to the name of the author; in this order each letter is then given a serial number (leaving several numbers in reserve between A, B, C, etc., for the insertion of any mail which may arrive during the day). Beginning with No. 1 each day, they are then recorded in a loose-leaf binder, alongside the number corresponding to the one which has been placed on the letter, as indicated here.

MAIL RECEIVED............... ....19....

No.	AUTHOR	DATE OF LETTER	SUBJECT	REFERRED	FILED
1					
2					
ETC.					

In the column "Referred" should appear the abbreviation of the name of the person to whom the letter is referred (as shown by the time-stamp on the letter) and the date; if the same letter is returned to the file clerk to be referred to another, a record to that effect is made alongside the original entry in the loose-leaf binder. When a letter is returned to be filed, the file number which appears on the letter should be recorded in the column headed "Filed," alongside the original entry, so that the letter may be readily located in the file.

The Headings. — The headings may be used as written, thus expressing a request; or to indicate work already done.

Abbreviation. — The abbreviation of a person's name opposite any heading expresses a request to do the work indicated.

The Initial. — An initial indicates work done.

Check Mark. — Checked abbreviation opposite INFOR. or ATTEN. indicates to the file clerk that the person whose abbreviation is checked has seen the document, but wishes it returned to him. After PR. CONF., PR. RPT., it has the additional significance that the work expressed by the heading opposite which it appears has been done by the person whose initial or abbreviation is checked. The person is not through with the letter, however, so he does not put his initial after ATT'D TO, but instead checks his abbreviation. After PR. RPLY, ACKN., and ANS., the date accomplishes the same purpose. *Date must always appear after these headings.*

The Arrow. — An arrow shows from which person a request to do work comes.

The Date. — The stamp should show the chronology of a document with respect to PR. RPLY, ACKN., ANS. and FILE. The date placed in the next vertical column to the right of these

headings accomplishes this. *None of these steps should be omitted in using the time stamp.*

INFOR. = Information, and means paper, letter, report, sketch, etc., sent to a person for his information.

ATTEN. = Attention, and means that the person to whom the paper is referred shall attend to whatever is required by the paper or that part of it to which his attention is directed.

PR. CONF. = Prepare for conference, and means look up any data necessary and then confer with the person referring the paper.

PR. RPT. = Prepare report, and means prepare a report on the subject matter of the paper.

PR. RPLY. = Prepare reply, and means to prepare a reply for the signature of the person referring the letter.

ACKN. = Acknowledge, and means acknowledge receipt of the paper.

ANS. = Answer, and means answer the letter.

(The headings PR. CONF., PR. RPT., PR. RPLY., ACKN., ANS., may also have the significance Conference prepared for, Report prepared, Reply prepared, Acknowledged, Answered, — meaning that work has been done by a person of his own volition. This is indicated by the initial instead of the abbreviation.)

AT'D TO = Attended to, and means that the paper has been attended to in accordance with the reference above.

It is to be remembered that these successive references are recorded by the file clerk, and *under no circumstances should documents be passed directly from one individual to another.*

Not more than one person's name shall appear in any vertical column.

The paper will be referred in the order of the names in the columns.

In order to avoid confusion, the file clerk shall determine the abbreviation of each person's name to be used and notify all concerned.

When the last person who is to attend to a paper shall have finished with it, he shall sign or stamp all his initials and the date after FILE. The paper shall then be returned to the file-room clerk. *Only the last man to attend to a paper should sign after* FILE.

The file clerk must not file any papers until *all* the ATT'D TO columns under the abbreviations in the upper part of the stamp are initialed, and FILE filled in by the *last person* who has seen the document.

All letters and reports originating in Headquarters Department must be sent to the file rooms to be press copied. Letters having green carbons shall not be forwarded until the carbon has been received in the file room.

No one except members of the filing force is to be allowed in the file room. File clerks must enforce this rule.

Filing and Indexing Letters, Reports and Other Communications.

Letters, reports, etc., are filed in letter-size four-drawer unit vertical files. File units can be placed side by side to provide any number of drawers needed as the papers accumulate. In the drawers are folders of stout manila paper, each large enough to hold about fifty papers.

The index is on 3 in. by 5 in. cards, both white and colored cards being used to make convenient distinctions to expedite search. The cards are kept in single trays or in cabinets of two or more drawers, according to the size of the index. These also are on the unit plan.

An OUT card 8½ in. by 11 in. is put in a folder whenever a letter is taken out, upon which is stated when the letter was taken out and to whom it was given. Guides or partition cards having metal tips containing labels or alphabetical or other tabs are used to subdivide the contents of a letter file drawer, to expedite the finding of a desired paper.

When a letter is kept out of the files over five days, a notice is sent to the person to whom the letter is charged, requesting him to return the letter with the notice or to renew it for five days more by marking "renew" on the notice. In any case, the notice is to be returned to the file room. This notice is repeated every five days until the letter is returned to the file room.

Special Files.

Most of the correspondence is filed in a general file with a general index. In Headquarters' office a few special files have been established and others may be added if found really necessary. A few similar special files may become advantageous in the field offices, but special files should be avoided, and with very few exceptions personal or individual files should not be allowed. Such files are likely to lead to confusion and so spoil a good system, besides causing unnecessary duplication of work and waste of stationery. Of course a man may withhold and properly care for communications of a semi-private or confiden-

tial nature which for obvious reasons should not be put in a general file.

The special files in Headquarters office are as follows:

1. Applications for employment.
2. Opinions of corporation counsel.
3. Communications of chief engineer to board.
4. Weekly and other routine reports.
5. Acceptances of appointments.

Applications for employment are filed alphabetically, according to the names of the applicants. For purposes of reference, applications are classified according to positions. These classes are indexed alphabetically, the name of each class being written on a guide card.

Opinions of corporation counsel are filed in chronological order and indexed in a special index under the subjects of which they treat.

Communications of the chief engineer to the board are numbered in chronological order and have a special index. Periodical routine reports are filed chronologically, each in its own series. Special indexes are made for them, as found necessary. Special reports are filed in the general file under the subjects of which they treat. Acceptances are filed alphabetically.

Contract Correspondence.

Correspondence concerning each of the formal numbered contracts is filed by itself according to the system described for the general file, using the same list of subjects so far as may be necessary. In these files each folder, besides having the regular subject number, has stamped conspicuously, CONTRACT NO. ——. Files of two or more contracts may be put into the same drawer and separated by suitable guides, each guide being plainly labeled with the number of its contract and the name of the contractor.

Filing and Indexing Drawings.

One employee in each office shall be held responsible for the proper filing of the drawings, and he alone should be allowed to put away drawings. In each office *all* drawings received from other offices should pass first through the hands of a designated

*	.... Department	.... Division
Accession Number	Title	Description Note principal feature of drawing

employee, possessed of sufficient knowledge, who will see that each drawing is properly introduced into the system of filing and indexing or otherwise attended to.

Drawings are filed in plan cases provided for the purpose and indexed on 3 in. by 5 in. cards kept in convenient cabinets. Cases and drawers are numbered. Plan cases have been designed on the unit system.

Besides bearing a file number to show where it is filed, each drawing is given an accession number which distinguishes it from all other drawings and, consequently, is the convenient and certain designation for the drawing in computations, correspondence or conversation. Accession sheets contain complete description and record of every drawing made or acquired by an office of the Bureau for permanent filing. There is a double space across the accession sheet for each drawing.

Headings are shown below.*

An accession number is given to a drawing as soon as it is well started — at any rate as soon as any computations are made relating to it. The exact title and description can be filled out on the accession sheet when they are determined. The tracing of a drawing is given a different accession number. As near the lower left-hand corner of the tracing as possible, usually in the margin, is placed the word "REFERENCES" followed by the accession numbers, one or more, of the drawing or drawings from which the tracing has been made. For example, if a tracing is made from Acc. 2000, it will be endorsed "REFERENCES" Acc. 2000. If made from 2000, 3000 and 4000 it will be endorsed "REFERENCES" Acc. 2000, 3000 and 4000. The brown paper studies will be endorsed "TRACED AS ACC. ———." The same record must be made in the "REMARKS" column of the accession sheet. If a drawing is revised or changes or additions made in it, it should be given a new accession number and endorsed with the date of the revision. One should be endorsed "REVISED FROM ACC. ———" and its predecessor should be marked "SUPERSEDED BY ACC. ———." The same note should be made on the Accession sheet under "REMARKS" and on the cards of the index. Revised drawings and prints of any kind upon which additional work is drawn are accessioned like new drawings.

SECTION.................. DATE..........................19 NO.........

DATE	PURPOSE OF DRAWING	SCALE H-HORIZONTAL V-VERTICAL	KIND OF PAPER. SIZE IN INCHES	WHERE FILE Case	WHERE FILE Drawer	INDEX UNDER	REMARKS

Generally, all drawings should be reaccessioned if lines are added or changes made on them, but drawings that show progress (progress diagrams), that is, drawings that are intended to be revised from time to time, should retain their original accession numbers and should be endorsed with the date of the latest change. The cross index cards should be similarly endorsed, and also the accession sheets. All previous editions of each drawing should be endorsed "REVISED TO" (the latest date).

Temporary accession sheets, properly numbered on the line for each drawing, will be kept in each drafting office, on which the draftsmen can make entries as needed. When a temporary sheet is filled, a new sheet properly numbered in advance is substituted. The filled sheet is promptly checked and corrected, and then sent to Headquarters or some other office having a large flat-platen typewriter, where it is neatly copied in triplicate. One copy, with the original, is returned, the second sent to the appropriate department office and the third retained at Headquarters. These copies are kept in suitable loose-leaf covers. After filing the final accession sheets and copies, the temporary sheets are destroyed.

In Headquarters department when a study, a map or a similar original drawing is to be accessioned, the designer or plotter takes it to the plan clerk and fills out the accession sheet so far as possible; the file clerk puts on the proper file number. "DESCRIPTION" should be filled out sufficiently for the drawing to be readily recognized when called for. Under "TITLE," if the title is not determined, shall be written in pencil the name of the individual to whom the drawing is charged. If the title is determined, it shall be entered and the name of the individual placed under "REMARKS." An employee shall keep track of all drawings thus charged to him. Likewise, draftsmen shall go to the plan clerk for file and accession numbers for tracings.

Under no circumstances shall a file or accession number be changed except by the plan clerk, who shall make corresponding changes on the accession sheets and the index cards. Every drawing, wherever found in an office, should show by its numbers or other endorsements that it has become a part of the system. Any drawings lacking the plan clerk's marks should be followed up to see why they have not been introduced into the system.

Contract drawings, besides accession and file numbers, are numbered consecutively in each contract set, as follows: "Contract No. 12, Sheet 20, Sheets in set, 45." For general use, contract drawings are lithographed to 11 in. in height, folded as

necessary, and bound in pamphlets $8\frac{1}{2}$ by 11 in., like the contract. Such lithographs, of course, bear the same designating numbers as the tracings from which they are made. Similarly, "working" drawings are photographed to about $7\frac{1}{2}$ by 11 in. and blueprinted for convenience and economy on sheets 11 by 14 in., thus avoiding the use of larger sheets in the field.

Blue prints and black prints may be given out by the plan clerk when authorized and no record need be kept, unless a print is stamped on its face "File Copy." In using prints for studies, employees should be especially careful to see that when lines are added or other changes made, they are reaccessioned like new drawings, if they are to be kept. The plan clerk, when receiving drawings, should observe file and accession numbers to see that the rules have been followed and to find out whether other copies of the same drawing have previously been received and are on file.

Drawings charged to individuals will be called for at the end of a month,* memoranda being sent by the plan clerk to each such individual weekly for drawings falling due during that week. Drawings may be renewed at the end of the month, if necessary. Individuals will be held strictly responsible for drawings charged to them and must afford the plan clerk every facility for locating them at any time. Drawings should not be passed from one individual to another in Headquarters office without going through the plan clerk's hands to have proper changes made on the records. It will aid in keeping track of a drawing, while outside the files, to attach a slip of paper reading: "Charged to Mr. ———. Do not remove or borrow."

Detail "working drawings" required under contracts for construction purposes are signed by the chief engineer. Such drawings must be prepared sufficiently in advance of the time when they will be needed to avoid delay to the field engineers and the contractor. If additional information is needed and is not received from the field early enough to allow ample time for the preparation of the drawing, the designing engineer responsible should send a request for the information, stating the time when it will be needed.

Working drawings are marked with the number of the contract in the same manner as the contract drawings. Most working drawings will be explanatory of some contract sheet. Each such working drawing is to be marked with the number of the sheet which it modifies with a letter to indicate its place in

* Would better be fortnight.

the order of progress, as follows: The first working drawing made to explain Sheet 26, Contract 12, is marked, "Contract 12. Sheet 26A. Working Drawing." Later working drawings explaining the same contract sheet shall be marked "26B," "26C," and so on.

Working drawings containing standard details applicable under several contracts will be marked in the upper right-hand corner "Working drawing," without a contract number, and will be designated by their accession numbers. If, under any contract, working drawings become necessary which cannot be considered the modification or explanation of one of the contract drawings, such sheets will be designated by their accession number only, but should contain, in the upper right-hand corner: "Contract No. ———. Working drawing ———."

If changes should become necessary on any signed tracing, especially a tracing which is to be lithographed, the assistant engineer in charge of the drafting room or the designing engineer (including architect, mechanical engineer and landscape engineer) who first gives orders for such change shall put a large blue-pencil cross over the department engineer's signature or the other signature which makes the tracing finally authoritative, thus indicating that it is to be changed. Such cross shall not be removed until the changes have been completed, checked by the designing engineer, and accepted by the party whose signature is crossed. Changes on important tracings which have been signed should be made only for weighty reasons. All errors which can be discovered by checking must be eliminated before the final signature is obtained.

The accession number is put in ink on each drawing in its lower right corner. The entry is made on the accession sheet as directed below.

Under TITLE, write the title of the drawing in full, excepting the two lines which appear on all drawings made in Board offices: City of New York, Board of Water Supply.

Under DESCRIPTION, write, briefly, enough about the drawing to tell what it shows. Do not repeat what is in the title, but supplement it. Abbreviations which can be readily interpreted may be used here.

In the column headed PURPOSE OF DRAWING, use the following abbreviations:

L Land plan, or map.
P Preliminary drawing or study.
C Contract drawing.
W Working drawing.

E	Estimate cross-section, progress diagram or similar drawing.
R	Record drawing (of completed construction work).
Z	Foreign drawing used for reference.

Under KIND OF PAPER AND SIZE IN INCHES, use the following abbreviations on the upper line, and on the lower line write the outside dimensions of the drawing:

W	White paper.
B	Brown paper.
T	Tracing cloth.
T P	Tracing paper.
W P	White print.
G P	Gray or green print.
B P	Blue print.
Black	Black print.
Lith	Lithograph.
Cr-Sec	Cross-section, paper or cloth.
T Cr-Sec	Tracing cross-section, paper or cloth.
Pro	Profile paper.
T Pro	Tracing profile paper.
Neg	Vandyke negative.
M	Mounted on cloth (to be written after other designation).

The column headed WHERE FILE should be filled *in pencil* with file number as soon as the drawing can be given a place in one of the plan cases. If the drawing should ever be put into another plan case, the numbers on the accession sheet should be changed at once, also the corresponding numbers on the drawing and on all index cards.

In the column headed INDEX UNDER shall be written a word, to be put on the index card, under which a person would naturally or properly look when searching for the drawing.

The different departments are designated by letters in filing, indexing and accessioning drawings, and have distinguishing colors for index cards. Foreign drawings, meaning those originating outside of this Board's jurisdiction, are designated by an X.

Divisions use their department colors and are designated by an additional initial. For example:

Northern Aqueduct department,	**N**
Esopus Division of ditto,	**NE**

Each field department office and division will accession all its drawings independently, each having a series of numbers beginning at 1 and using its department and division letter. In Headquarters, only one series will be used, the numbers being assigned by the Drafting division. Thus: 491, S 5440 and R 721 indicate drawings originated in the Headquarters, Southern Aqueduct and Reservoir department offices respectively, and NE 299 is the accession number of a drawing originated in

one of the offices of the Esopus division of the Northern Aqueduct department. Division offices will supply section offices with accession numbers by sending temporary accession sheets properly numbered in advance. Section office drawings will be accessioned as though they originated at division offices; that is, a section office will not have an independent series of numbers, but will use blocks of numbers in the division series.

Two indexes are provided for drawings in Headquarters office. First, an index by accession numbers on Form 256 E, with Form 270 E printed on the back, the cards being arranged by accession numbers; and, second, an alphabetical index in which the cards are written under local terms, elemental topics, a predominant feature of the drawing or the most likely subject by which the drawing wlll be asked for. Several cards may be in the second index for the same drawing. The main card will be of the color of the department in which the drawing originates or is received from a source outside the Board's offices, and the cross reference cards are white. All cross references should be noted on the main card, so that all cards may be readily located in the index. The following form is used for this index:

A TO Z INDEX

TITLE

	ACC.
DATE	SIZE
PURPOSE	FILE
SCALE	KIND

All drawings in each department and division office shall be indexed on SUBJECT cards, the distinguishing color of the department where the drawing originated being used. All of these cards are kept in the same index. The guide cards are buff colored.

Cross-references are made in sufficient number to insure the finding of the drawing, plain white cards being used. Index cards are typewritten so far as practicable.

Drawings or copies of drawings from other board offices, if filed in the office where received, are indexed on RECEIVED cards of the color of the department from which they come, these cards being kept as a separate index. In the Headquarters accession sheet of the department from which they come, note under REMARKS as follows: Hqs. Copy Case......Dr......

Should any drawing be sent to another office for permanent or temporary filing, or taken from its files for any other purpose for any considerable length of time, a proper note should be made on the back of its index card. Receipt should be taken for any drawing leaving its file.

Division engineers may, if they see fit, devise methods of indexing their section office drawings so as to distinguish them from those originating in division offices.

If any drawing which has been given an accession number be destroyed or sent *permanently* from the office in which it was filed, a note of the facts shall be made in REMARKS column opposite the correct number on the final accession sheet.

Filing and Indexing Photographs.

Photographs (negatives) are to be of uniform sizes, 6½ in. by 8½ in. for outdoor work and 7 in. by 10 in. for copying drawings. For special work suitable sizes may be permitted. Finished photographs for the official file at Headquarters office are to be printed on 8½ in. by 11 in. heavy unmounted Velox, platinum or other paper giving a permanent black or gray picture on white ground. Photographs for department files may be like those for Headquarters, or blue prints.

Each department and each division is to number the negatives taken by its own photographer in a series of its own, beginning at 1 and using the department abbreviation and division initial, and to keep an index of photographs by numbers with the necessary cross-references. Negatives taken by the official photographer are to be numbered in another series, using the abbreviation Hdq., with the initial of the department in which the photograph was taken. Each negative is marked in the lower right-hand corner with the date and accession number. Negatives are stored in Headquarters office.

Official files of photographs in Headquarters and field department offices are kept in standard 8½ in. by 11 in. letter file drawers. Files are divided, so as to keep photographs of real estate, construction progress photographs, and photographs for accident and damage cases separate. Each class should be subdivided by metal-tip guide cards, according to locality or subject. In each subdivision the pictures should be arranged in chronological order. An OUT card should be used if a photograph is taken from the file.

Filing and Indexing Catalogues and Circulars.

Catalogues and circulars are numbered and filed according to size:

Up to 7 by 9 in. . . . . 1 to 1 000
7 by 9 in. to 9 by $11\frac{1}{2}$ in. . . . . 1 001 to 2 000
Larger than 9 by $11\frac{1}{2}$ in. . . . . 2 001 to 3 000

If needed, additional blocks of numbers will be assigned.

Catalogues are alphabetically indexed on 3 by 5 in. cards, under firm names and subjects.

Computations.

For survey computations, such as stadia notes and traverse tables, and for estimates for payments under contracts, special sheets are provided. Each assistant engaged upon general computations is furnished with an *individual* computation cover holding standard punched computation sheets, $8\frac{1}{2}$ in. by 11 in. size, with printed blank heading, thus:

Subject. . . . . File No. . . . .
. . . . Acc. No. . . . .
. . . . Sheet. . . . Tot. in Comp. . . . . .
Computer. . . . . Checked by. . . . . Date . . . . 19. . . .
Made in Connection with

All general computations must be made in *ink* on these sheets, using one side only, except as otherwise directed by a department or division engineer. This makes it possible to get a print of any sheet, if needed, and thus save copying. The margin on the left of each sheet must be kept blank.

In the Distribution division the standard filing system of the engineering bureau is supplemented by dividing field notes according to coördinates. A key-map covering all the ground of the distribution division (Greater New York) has been prepared and coördinates plotted on it to the nearest 20 000 ft., the center of each square being marked by a dot. Smaller maps are prepared of each 10 000 ft. sq. on a scale of 1 in. = 2 000 ft. The north coördinates run into hundreds of thousands, while the east do not exceed tens of thousands. Whole figures are used to designate points to the nearest thousand feet by making the two figures to the left of the decimal point represent the east coördinate to the nearest thousand feet, while the figures farther to the left represent the north coördinate to the nearest thousand feet. For location to the nearest hundred feet, the first figure to the right of the decimal point represents the north coördinate, while the second represents the east: Thus, 15 426.63 = 154 600 N and 26 300 E; 15 426 = 154 000 N and 26 000 E. This could be extended to locate points to the nearest foot, if necessary, by increasing the number of decimal places. Notes

numbered in this manner are filed numerically. Surveying notes should ordinarily be located to the nearest thousand feet, and construction notes to the nearest hundred.

Subject List.

A subject list is a scheme of classification of the data collected, and is, consequently, the basis of indexing. To conceive and properly arrange a list of subjects with a suitable method of numbering was the difficult task. Two or three attempts were made before the list in use was adopted. Its numbers and letters, which are the symbols for the subjects, furnish a system of brief and specific designations by which references can be conveniently made, especially in computations.

Assistant engineers in charge of computations should, therefore, be thoroughly familiar with the index so that they may choose their titles and arrange their computations in such a way on successive sheets that they can be readily filed by the index as it exists. It frequently happens that individual computers do not see much beyond the work that they are engaged upon, so that they are incompetent to write a proper title or fill out the heading, "Made in connection with." Likewise those in charge of filing and indexing letters, reports, drawings, etc., need to know the subject list very thoroughly.

The index is not intended to be adequate for *all* the detail that arises in some instances, and a liberal use of tab cards for further segregation is contemplated beyond its scope. The assistant engineer at headquarters, in general charge of filing and indexing, should recognize local needs and not endeavor to construe the index for cases where it obviously does not apply or where a local method of filing and indexing "beyond the scope of the index" would better meet the requirements. For example, L 3.0A is the file number for real estate data of Ashokan Reservoir, but the file is more readily further subdivided by parcel and claimant numbers than by any of the subdivisions of reservoir given in this index.

The SUBJECT LIST embraces two parts, and the index correspondingly divided.

First, the list of *MAIN STRUCTURES* to be built by the board.

Second, the *GENERAL SUBJECT LIST* (a list of materials and methods, bibliography of structures similar to the "main structures," etc.).

For ease in consulting, the index is arranged as follows:

Under each of the "Main Structures" the subdivisions are arranged alphabetically (A to Z) and numerically by file numbers, beginning with 1 (1 to *n*).* The "General List" is arranged alphabetically (A to Z) and numerically beginning with 1 (1 to *n*). The same subjects appear in both the numeric index and the alphabetic, with the same file numbers, with the exception that cross-references are given in the alphabetic index while none appear in the numeric index, so that the distinction is one of arrangement and function, the alphabetic index enabling a person unfamiliar with the system to locate matter in the files, while the numeric index would be used by the initiated.

In the alphabetic index the subdivisions of each of the main structures are arranged alphabetically and the general list is arranged alphabetically throughout.

In the numeric index each subject is given an integral number and its subdivisions are given a decimal as in the Dewey system. The first eleven subjects are structures which will probably be built by the board. Some of these subjects, as *watersheds*, *reservoirs*, *aqueducts*, *filters*, *distributing conduits*, follow each other in the logical succession of their utility, while others, for example, *aëration works*, *water-power development*, *pumping and power stations*, are more or less collateral in their relation to the former. Each of these subjects is fully subdivided, while the rest of the list (i. e., the General List) may be added to or developed as necessary. For works of a different class, naturally, the subject list and index would be differently arranged; some topics which are now made principal headings would become minor, and some of the minor items would become the principal headings, as, for example, in a water-power development or railroad project.

The principle of the subdivisions of the main structures is perhaps most easily understood on the basis of cost. In estimating the cost of a structure, everything which its construction occasions is charged against it; similarly, everything likely to arise in the construction of any particular structure has a place in the index under some subdivisions of the integral number representing the structure. Under *reservoirs*, for example, the main subdivisions are, *improvement of site*, *dams and dikes*, *conduits and piping*, *gate-houses*, *highway construction*, *railroad construction*, *lighting and telephone* and *special structures*, all likely

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* *n* is used, as commonly in algebraic formulas, to mean an indefinite number which cannot conveniently be stated precisely but which is readily determined by given conditions in a specific case.

to enter into the construction and design of a reservoir. The same is true of aqueducts and of all the other main structures. It is apparent, therefore, that some subjects, such as *railroad relocation*, may have several file numbers, selections of file number in any instance depending upon which structure the work was " done in connection with."

The " MAIN STRUCTURES " referred to are as follows:

1.0 General Schemes of Water Supply. (Summaries, etc., involving more than one of the main structures.)
2.0 *Watershed.* Rainfall. Stream Flow.
3.0 *Reservoir.* Dams and Dikes. River Control. Gate-houses.
4.0 *Infiltration Galleries and Wells.* (Not borings for Geologic investigation.) California Stovepipe Wells.
5.0 *Aqueducts.* Cut and Cover. Grade Tunnel.
Siphons. Steel Pipe. Pressure Tunnel. Reinforced Concrete Pipe. Iron Pipe.
6.0 Filters (Slow Sand).
7.0 Mechanical Filters.
8.0 Distributing Conduits. (Street mains, not main pipes to Brooklyn or Richmond, for which see AQUEDUCTS.)
9.0 Aëration Works.
10.0 Water-Power Development. (Not power plant or machinery, for which see 11.0.)
11.0 Plants, general (power, pumping, contractor's plant, etc.; miscellaneous machinery).
59.0 Civil Service.
72.0 Organization.

Intermediate numbers have been left so that new subjects may be added more nearly in their logical sequence.

The rest of the index, known as the general index or the " GENERAL SUBJECT LIST," is made up, as has been stated, of a list of subjects pertaining to engineering methods, articles, materials, etc., investigations on which are general and should, for the purpose of reference, be so indexed, though they may have been " made in connection with " some special structure.

Difficulty may arise in some cases, however, in differentiating between matter which should be indexed under some special structure or under a heading of the general list, and each paper should be carefully scrutinized before indexing to determine its bearing on the work. This difficulty may be minimized, however, at the time papers originate, by remembering that the subject list is the mold into which they must be cast. Even with great care in indexing, data of general import will find their way into the files of some special structure for reasons of expediency or the personal equation of the indexer, so that a person consulting the general reference file should bear in mind that he may find data on his subject in the file of a special structure.

Treatment and Locality Letters.

In addition to the file number, treatment letters are used before the file number indicating the point of view from which the subject is considered, and after the file number a locality letter is used to distinguish between structures of the same kind but occurring in different places. For example, the file number of *aqueducts, general*, is 5.0, while D 5.0 is a general problem of aqueduct design, the treatment letter D representing design; D 5.0 C is a general problem of design for the Catskill *aqueduct*, the C representing Catskill aqueduct. P 5.3 CG is a preliminary estimate of cost of the Garrison tunnel of the Catskill aqueduct, P being preliminary estimate; 5, aqueduct; .3, grade tunnel; C, Catskill aqueduct; and G, Garrison tunnel. B 5.0 W is general information on the Wachusett aqueduct, B standing for outside information and W, the locality letter for Wachusett aqueduct.

Treatment Letters for Field and Office Work, to be used before File Numbers, in Filing Correspondence, Field Notes, Plans, Computations, etc.

Capital and small letters are given for the same definition. The small letters are used on notes, etc., made in the field, while the capitals are for office use, in order to show without further explanation in referencing whether a field or office note or computation is referred to. In the case of plans and correspondence, which are always office products (plane table work and sketches excepted), capital letters are uniformly used, and not the small letters.

Where note appears with any treatment letter stating that it may or may not be used with any of the classes of data to be filed, namely, plans, computations, correspondence, etc., the notes are provisional in so far as no cases have arisen that would make their use apparent. When any such cases do arise, attention of Headquarters should be called to them, so that the change may be made uniform for all offices.

"Correspondence" is used here broadly to indicate any matter, letters, reports, etc., that are filed in the vertical 8½ in. by 11 in. file.

The word "foreign" is used in reference to works not under the jurisdiction of the board.

Definitions of Treatment Letters.

F. Field Work. Trigonometric and other *office computations based on field notes* for use in laying out work or making

field work available for subsequent use in either the office or field study or design or construction. Subdivide by field treatment letters if desired. Data taken from the field notes should be referenced on office computation sheets by file number, with the small letter showing the nature of the field note prefixed, as: l 5.0 C is a reference on an office computation to a field note of a landtaking survey on the Catskill aqueduct. The computation sheet on which this reference appears would have the file number Fl 5.0 C.

As a general thing, office computations will be on $8\frac{1}{2}$ in. by 11 in. sheets and field notes on 5 in. by 8 in. sheets. The small letters, therefore, will appear before file numbers on 5 in. by 8 in. sheets and the capitals before file numbers on $8\frac{1}{2}$ in. by 11 in. sheets.

Fl 5.0 C. Office work or computations on landtaking survey notes on aqueduct.

F △ 3.0 A. Office work or computations on Ashokan Reservoir triangulation field notes.

D. Studies and Designs. Including computations of ideal quantities and costs per foot; also including *estimates of cost for use in comparing alternative schemes*, or comparing alternative types of construction, locations or designs of a structure. May be used for filing plans, computations and in correspondence file for reports and letters. Brown paper or other plans that constitute studies or designs will have this letter prefixed to the subject file number. This will serve to separate the study drawings from topographic plans of the same structure, the latter having the prefix Z before the file number.

When topographic plans have lines drawn on them showing the probable location of an aqueduct, dam or other structure, they then become studies of location and should have the treatment letter D before the file number. Such drawings as a rule should be reaccessioned, as the added lines have altered the drawings from their original descriptions on the accession sheets. The original topographic plans which show a broad strip of country in the general vicinity of the above-mentioned location will have the prefix Z before the file number.

Contract drawings will be filed by contract and may have either Z or D prefixed if desired. Cont. No. 2, 5.2 C, is the file number of plans for cut-and-cover sections of the Catskill aqueduct, Contract No. 2.

Plans of a general nature that could be used for subsequent contracts, but were " made in connection with " some particular

contract, should be filed in a "Contract, General," or "All Contracts" file and cross-referenced under the specific contract which they were "made in connection with."

P. Preliminary Estimates. Calculations made on a scheme, structure or section of work for which the type of construction is already determined or assumed, for the purpose of finding its probable cost *for financial purposes*, not for comparing designs. (The engineer's formal estimate, which is computed by items just as they appear in the contract, is put below. See *E.*)

P may be conveniently used in some cases for estimates of time as well as cost, as, for example, in the correspondence file a report on the probable time and sequence of letting contracts or an estimate of the time of completion of the Garrison tunnel. P may be used for computations or correspondence. The phrase "for financial purposes" constitutes the difference between P and D. Data for a comptroller's estimate, for example, should have P.

p. Measurements for Estimate for Partial Payment.

E. Contract Estimates. Includes the formal, preliminary, engineer's estimate, and all estimates for payment. Not used ordinarily for plans or correspondence.

L. Land Takings and Damages, Real Estate, etc. Used for plans, computations and correspondence on the main structures to be built by the board.

l. Land Taking Surveys.

T and t. Tests and Inspection. Also experiments. T used for plans, computations, correspondence, laboratory work, tests, experiments and laboratory records. Statistics or records of foreign work have the prefix B in preference to T, or, if it appears desirable, B may be subdivided by T, as BT 18.33, a foreign compressive test on cement; but in filing the B should be given the precedence, that is, filed by B first and then under T or other treatment letter.

G and g. Geology and Underground Investigations. Includes borings and test pits, etc. G may be used for plans, computations, correspondence, etc.

K and k. Cost, by Force Accounts, on Board of Water Supply Work. Cost on other works, see B. Not ordinarily used for plans or correspondence. Use k for field data.

S. Specifications. Used before file number of materials or structures, not before 72.12 or 72.15. Not ordinarily used for plans or correspondence.

B. Bibliography. Includes all information in regard to

"foreign" works gathered by members of the Board of Water Supply force or outside data made by outside people. Used for computations, correspondence, drawings. This letter is applied to foreign data only, and it takes precedence in the order of filing over any of the other letters, the use of which might be indicated in any particular case. For example, a record of borings on the Pennsylvania tunnels could have the file number G 71.0 (71.0 = Tunnels, General), according to the definition of G; but it is better to use B in order to separate foreign boring data from that originating in the Board's offices; and 70.0 (70.0 = Borings, General) instead of 71.0, as the data collected were for general information on borings regardless of their relation to tunnels. If sufficient information is collected on any of the subjects, it might be advisable to subdivide B by the other letters, as BG, foreign geologic information, etc. Always file by B first, however.

△. *Triangulation.* May be used for plans if desired. Not ordinarily used in correspondence file.

Z and z. Topography. Topographic surveys for any structure. Use Z on topographic plans. See definition of D.

bl. Bench Levels.

y. Line and Grade for Construction.

R and r. Record Measurement. On completed work, including measurement for final estimate.

R may be used for record plans; Fr for record computations, etc.

The LOCALITY LETTERS may be chosen as necessity demands by those locally concerned, but they should not be used before notifying Headquarters, in order that duplications may be avoided. An index of these abbreviations should be kept in each office and additions will be sent from Headquarters, where a general index of all abbreviations will be kept. Headquarters should, therefore, be notified at once of the desire to use an abbreviation or locality letter after the file number where one does not already exist.

The same course should be followed in the establishing of new subjects or the classifying of subjects under the general heads given. These should be sent to Headquarters with the suggestion of the proper filing place; a decision will then be made and transmitted to all the offices. A card index to these decisions will be kept at Headquarters to insure filing similar data always in the same place.

By the use of these treatment and locality letters it is possi-

ble to separate data of a given kind on any structure or part thereof from all other information of the same character or similar information about other structures of the same kind.

In certain cases doubt may arise as to the proper file number to select for a particular topic. For example, referring to the general list and the TREATMENT LETTERS:

G = Borings and underground investigations.
70.0 = Borings, general.
Ag. 23 = Borings on aqueduct line under Agreement No. 23.
G 5.0 C = Borings on Catskill aqueduct.
72.15 = Agreements.
70.2 = Boring apparatus.
B 11.0 = Contractor's plant.

The question might readily arise as to where these numbers should be used, and undoubtedly there would be border-line cases where no two individuals would index the same, but in general as follows:

Index general information on borings under 70.0, using B 70.0 for outside data. Index general information on boring rigs under 70.2, using B 70.2 when contractor's plant. (If the work was done by the board, it would not be filed in an agreement folder or with the letter B, but in the general file, using the subject-list topics for subdivision.)

Index general information about *agreements*, *specifications for agreements*, *requests for bids*, etc., under 72.15.

Use B 11.0 for a large plant as in agreement 37, but file the boring rigs under B 70.2.

It should be observed that the General Subject List contains the "MAIN STRUCTURES" and some of their subdivisions with the same file numbers that they have when considered as "MAIN STRUCTURES" and subdivisions thereof, the distinction arising in the use of the locality letter after the file number. For example:

Reservoir, GENERAL SUBJECT LIST — 3.0 or B 3.0 Cr. [B, foreign data; Cr., Croton].

Reservoir as MAIN STRUCTURE to be built — 3.0 A [A, Ashokan Res.].

The letters before and after the file number could be used similarly for any of the subdivisions of reservoirs. For example:

Dams, GENERAL SUBJECT LIST — 3.4 or B 3.4 Cr.

Dams Sub. of the MAIN STRUCTURE — 3.4 AO [Ashokan Reservoir, Olive Bridge Dam].

In some cases where a subject appears under each of the main structures a different file number is given to it in the gen-

eral list. For example, excavation appears many times in the index under each of the main structures, so that *excavation, general*, is given a distinctive file number in the general list. On the contrary, the only place where dams occur is as a subdivision of *reservoir*, and consequently the same file number is used for dams in the general list.

Before making additions to the general list these cases should be borne in mind so that unnecessary duplication of file numbers for the same topic may be avoided. Wherever a topic has several file numbers already under the main structures, it is better to establish a new one in the general list rather than arbitrarily to select one of the many for the general index, trusting to the locality letters to accomplish the desired separation of general from specific data.

Reference to the numeric index will show that in some instances illogical arrangements have been permitted in order to avoid duplication of the file numbers for the same topic, and the consequent uncertainty and doubt in indexing and locating matter in the files. For example: ACCIDENTS 72.34 appears as a subdivision of employees under Organization, and all data about PERSONAL ACCIDENTS, whether to employees or not, is filed here rather than establish another number for "ACCIDENTS" in general list. Similarly, *steel pipe* appears as a subdivision of siphons with the file number 5.42, and all general information on *steel pipe* is filed here, whether about siphon or not.

As an example to illustrate the system, one of the decimal divisions of the numeric index is here reproduced, viz., the decimal class .4, embracing the subject of Dams, under the unit 3, RESERVOIRS, as numbered among the MAIN STRUCTURES. It extends from 3.4 to 3.465:

3.4 Dams and dikes, to be known by letters, Board of Water Supply dams to be filed under their respective reservoirs; foreign dams, even when important enough to be represented by a letter, to be filed under reservoirs and dams in general. Method shown in following list:

3.4AO Olive Bridge Dam of Ashokan Reservoir.
3.4AT Tongore Dam ,, ,, ,,
3.4AA Ashton Dam ,, ,, ,,
3.4AB Brown's Station Dike of Ashokan Reservoir.
3.4KV Valhalla Dam of Kensico Reservoir.
3.4Q Quaker Bridge Dam (of Croton Reservoir, but not so filed).
Relative advantages of site; availability of, with reference to topographical and geological features, etc. (General. Use tabs, if desired).

3.41 Theory. (Divisions of design.)
.412 Ice thrust.
.413 Upward water pressure.
.414 Vacuum.
.415 Internal stresses.
.416 Temperature. Cracks. Expansion joints. Interior drainage.
.42 Earth Dams or Dike (materials and methods of construction).
(Location. Site. Cross-sections. Profiles.) Use tabs to divide if necessary, under 3.42.
.421 Theory (not included under 3.41).
.422 Preparation of foundation excavation.
.423 Earth work of dam, filling, etc.
.424 Core-walls.
.425 Paving and riprap,sodding, slope protection, etc.
.426 Prevention of leakage — drainage.
.43 Masonry Dams, cyclopean, rubble, concrete, etc., not overfall sect.
(Materials and methods of construction. Location. Site. Cross-sections. Profiles.) General. Separate under 3.43 if necessary.
.431 Theory (not included under 3.41).
.432 Excavation. Earth and rock. Preparation. Foundation, Faults. Seams. Springs, etc.
.433 Embankment.
.434 Masonry.
.435 Interior drainage.
.436 Gate Houses, if monolithic with dam (piping and appurtenances).
.437 Finishing.
.44 Masonry Dams. Overfall sections, waste weirs. Spillway.
(Location. Site. Cross-sections. Profiles. Materials and methods of construction.) General. Separate under 3.44 if necessary.
.441 Theory (not included under 3.41). (Waste channels, capacity of flow, etc.)
.442 Excavation, earth and rock.
.443 Embankment.
.444 Masonry.
.445 Interior Drainage.
.446 Gate Houses.
.447 Special Structures.
.45 Reinforced Concrete and Other Dams (not Cofferdams).
.46 River Control.
.462 Cofferdams and Other Temporary Dams. Cribs.
.463 Flumes (not for general use. Flumes, general, see 5.5).
.464 Pipes. Conduits. Culverts.
.465 Regulating Devices, Gates, etc.

The bearing and effect of the heading, "MADE IN CONNECTION WITH," is well illustrated by the exception in the case of steel pipe for river control at Olive Bridge Dam, which is filed under the proper subdivision of reservoir, namely, 3.464 AO (A, Ashokan; O, Olive Bridge). It is far better to accept the system as applied to general and miscellaneous matter merely as an arbitrary set of numbers corresponding to certain topics, resolutely dismissing rigid ideas of logical sequence and consistency, except in the case of matter relating to the main structures to be built, wherein the logical arrangement can be more closely followed. The list is manifestly incomplete when considering isolated topics, and in most instances it will

not be advisable to establish new integral file numbers for all subjects that come up, but rather to classify them if possible by the general heads which already exist and write a card in the alphabetical index for the particular topic, for the guidance of those uninitiated in the logic of the system, and to aid file clerks in filing similar data under the same head. Later, if the data on any topic increase, a decimal subdivision under the general head can be assigned and collected matter filed there. For example: the topic "Hydraulic Tests of Rock" does not have a distinctive file number, but is filed in 70.0, the file number of "Borings, General," when the boring was not made in connection with a particular structure. "Hydraulic Tests at Olive Bridge Dam Site" could, if desirable, be filed in G 3.4 AO. In the alphabetic index, however, under T we find the heading "Tests, Hydraulic, of Rock," with the file number 70.0 for general information on this subject, and other file numbers in case work of this character was made in connection with one of the main structures and filed there. Later it might appear advantageous to assign some decimal subdivision of 70.0 as the file number for general information on this particular topic.

General.

It is not possible to foresee all cases wherein ambiguity will crop out on application and set down hard and fast rules in advance for guidance of file clerks. Hence the importance of maintaining close communication between file clerks in the field offices and Headquarters is emphasized. As these points come up, they should be referred to the Headquarters office for settlement and, if file clerks have individual opinions, they should state them, giving at the same time reasons for their point of view. The final settlement should be transmitted to all the offices for uniform adoption.

Explanations will be found throughout the numeric index at various points where deemed necessary. These should be read before endeavoring to apply the filing system.

Actual experience with this system has shown that legitimate differences of interpretation of the index are constantly occurring, due to individual point of view, so that in many cases more or less arbitrary or illogical rules must be adopted for the sake of uniformity at these points of uncertain definition. It is obvious that these rules, as well as the index, must be made uniform. As a general principle, therefore, it is expedient to trust the work of filing and indexing to as few persons as condi-

tions will permit, and to avoid local interpretations by referring doubts to Headquarters office for final settlement.

Contract Files.

Separate files are to be provided for each contract, and matter will be further divided and filed by item (where desired) as well as by the file number.

As construction progresses, more data in the engineering bureau will be filed under individual contracts and less in the general file. It will evidently be desirable to have the numbers by which contracts and agreements are to be designated assigned as soon as practicable, so that matter can be marked with contract number and filed in the contract file, otherwise a good deal of preliminary data which viewed in retrospect belongs as properly in the contract file as that originating after the contract number has been fixed will necessarily be filed in the general file.

The method of filing by item and file number admits of two possibilities, namely, division of the item by file number and division of the file number by item. Under cut-and-cover aqueduct, for example, the file number of excavation is 5.23, which may be further subdivided under Contract No. 2 as 5.23 C, Contract No. 2, item No. 1, which reads " Excavation between Stations 100 and 200." Again, under grade tunnel, excavation (5.33 C G, Contract No. 2, item 34) reads enlargement of tunnel section in earth, 5 being the file number of aqueduct, .3 the type of aqueduct called " grade tunnel," .33, " excavation in grade tunnel," C, Catskill aqueduct " and G, " Garrison tunnel." Conversely, a given item of concrete or excavation may be split up by file numbers and apportioned among several structures or parts of the work.

When it is considered that a contract is, as a rule, for one class of work, represented in the index by a single file number (see Contract No. 2; largely " cut-and-cover aqueduct "; file No. 5.2; and " grade tunnel," file No. 5.3) which may or may not be subdivided sufficiently to accommodate the large amount of correspondence and other data that is certain to accumulate during its pursuance, it is a decided advantage to file by item in the contract files. Abstractly, it is quite immaterial whether the segregation is accomplished by file numbers representing certain topics or by item numbers representing the identical topics, the advantage in practice lying with the latter method, viz., in that file numbers for details may be curtailed in the gen-

eral list without sacrificing minute subdivision in the contract files where correspondence, etc., on details accumulates. Moreover, the definition of an item number becomes fixed in the minds of those engaged on contract work, and it is, therefore, not an unnatural division or an unusual line along which to require persons to think. On the contrary, field men will find it a distinct advantage in contract work generally to avoid the duplication of file numbers and items and the necessity of memorizing a confusing relation between them, which would otherwise be the inevitable result.

Just as instructions forbid discussing more than one subject, one contract or one agreement in a letter or other document, it is essential to this method of filing that a communication deal with only one item, and contractors as well as the engineers should be accustomed, by having their attention repeatedly called to transgressions, to follow this method in correspondence. Some data, of course, will be of a general nature wherein several items of a contract or the work in general will be discussed, and these should, of course, be filed by the proper file number in the contract file. In some cases it may happen during the course of a contract that something would come up of value on contracts in general or of important bearing on future contracts, and it would, therefore, be desirable to have this information given in an ALL CONTRACT or GENERAL CONTRACT file and not obscured in the file of any one contract. This can be accomplished by copying the data and filing the copy under CONTRACTS, GENERAL, 72.12, or cross-indexing it on the cards of the general index.

At the head of each contract file a list of the items should be kept as an index, since the item number represents a different topic in each contract.

"Loose leaf" methods have been followed so far as practicable. Useless papers are removed from the files and destroyed from time to time. This, of course, requires care, and doubtful cases are referred by the file clerk to some one in authority. Searches for general information in the libraries of the board and of individuals, as well as in outside libraries, in engineering periodicals and in the manuscript reports in the files are made by a librarian, at considerable economy of time for the engineers and regular filing force.

If the system seems complicated from its completeness and the comprehensiveness of this description, remember that the

organization and works for which it has been devised constitute one of the most extensive, costly and difficult engineering projects ever undertaken.

No more fitting close for this paper can be written than the letter of Chief Engineer J. Waldo Smith, transmitting the book of regulations to the members of the Engineering Bureau: "These general regulations have been prepared to insure uniform and correct methods in all departments of the Engineering Bureau. They must be carefully studied and conscientiously observed. Obviously some details will have to be determined by each department engineer for the peculiar requirements of his work. Special rules, whenever they are necessary, must harmonize with these general instructions.

"Systems will not run themselves. Success depends upon the faithfulness of men. Each member of the force is expected to coöperate loyally with the others in maintaining a high degree of efficiency in all the work of the Bureau."

[NOTE. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by January 1, 1910, for publication in a subsequent number of the JOURNAL.]

GOING VALUE AS AN ELEMENT IN THE APPRAISAL OF PUBLIC UTILITY PROPERTIES.

By William H. Bryan, Member Engineers' Club of St. Louis.

[Read before the Club, October 20, 1909.]

Appraisals of public utility plants are made for a variety of purposes — sale, bond issues, taxation — and more often in recent years as a basis for rate-making, a function which is coming more and more to be exercised by state or municipal authorities.

Such appraisals must cover both the tangible and the intangible values. The former present no great difficulty, being usually taken as the present cost of duplicating the property used and useful for the convenience of the public, less depreciation. The intangible values are usually two in number, "franchise" and "going" value.

Where the utility is operating under an existing franchise, future net earnings during the unexpired period are estimated. These, when reduced to present worth, fairly represent franchise value. Where the franchise has expired, or where the municipality has the right to purchase at stipulated periods, there is, of course, no franchise value.

Going value, however, may continue even after the franchise has expired so long as the plant continues to serve the community. This value was first officially recognized in Judge Brewer's decision of the Kansas City Water Works case (see United States Federal Reports, 62–853) in the following language: "The city steps into possession of a property which not only has the ability to earn, but is, in fact, earning. It should pay, therefore, not merely the value of a system which might be made to earn, but that of a system which does earn."

It is an infortunate fact, however, that agreement is still far from general among engineers both as to the exact definition of going value and the proper method of determining its value. This is well illustrated in a recent compilation * of twenty valuations, in which it varies all the way from 0 to 47 per cent. of the

* "Notes on Going Value and Methods for Its Computation," by John W. Alvord, presented at the Milwaukee Convention, American Water Works Association, June, 1909.

physical value of the plant. Even wider ranges would probably be found if all the appraisals in which it has been considered by able engineers of varying view-points could be compiled and compared. In one of the most important appraisals of recent years, in the hands of five of the leading specialists of the country, no two of them agreed as to the method of computation.

There is, however, much evidence indicating that substantial progress is being made towards clearer and fairer views. The author ventures to indulge the hope that it may soon be possible to so handle this matter that the justice and fairness of our methods will be so apparent as to appeal, not only to specialists, but to judges and juries and to mayors and boards of aldermen as well. There must surely be a way to so determine going value as to satisfy both seller and purchaser.

Perhaps the clearest official utterances thus far made on this subject are the recent decisions of the State Railway Commission of Wisconsin. In the Cashton Light and Power Company case they said:

"The element of 'going value' created by the investments made in developing the business and in addition to the cost of the physical structure must be taken into consideration in fixing value; although the franchise of a public utility operating under an indeterminate permit has expired upon the exercise by the municipality of its option to purchase, the plant is to be taken over as a going concern, and just compensation must be awarded for the property taken as a living and operating entity, engaged in serving the public, and not as a mere plant without patrons and without privilege or right to operate and to serve the public and having but a salvage value."

Also in the Antigo water and the Marinette telephone cases:

"The theory of the Wisconsin public utilities law is that rates shall be reasonable and shall be not greater than enough to yield a fair return on the investment. In determining the investment as a preliminary process to the fixing of rates, the Commission had to deal with the claims of large 'intangible' franchise values as well as 'going values,' in both the Antigo water case and the Marinette telephone case. Regarding the former, the Commission holds that if the municipality required the payment of money or its equivalent, or there was necessary legitimate payment made for the franchise, then the sum which may reasonably be said to have been paid for the franchise may be included in the valuation, the same as money necessarily invested in the physical property. But the Commission refuses to consider the claims of some experts and corporations that franchises for which no money was paid may have 'intangible' values which should be considered in the making of rates.

"It has been held by experts that 'going value' should be allowed as so much per customer, or as a percentage of the receipts, and some have considered it of as great, if not greater, importance than the physical value of the plant. The Commission holds that the actual reasonably wise expenditure of money towards getting the business of the plant established may be included in the value to be allowed for the purpose of fixing rates. Since no plant pays at the outset, and the first years of operation are almost invariably accompanied by losses or necessary deficits, the Commission holds that such losses may be said to represent the cost of securing an established or going business, and as such may be included in the value or investment upon which the rates for public service shall be fixed. But the converse of the rule also holds; that is, if a plant has in the past earned more than a reasonable return, possibly through the toleration of excessive rates, the excess over reasonable earnings may, under certain conditions, be subtracted in determining the present value of the plant. That is, a 'going value' may be negative. In the case of the Marinette Telephone Company, for example, the Commission found upon its investigation of the financial history of the company that through a period of recent years the company had been enjoying a sufficiently high rate of return to write off the early deficits in so far as such deficits might be allowed as going value."

It may be noted in passing that the now generally accepted view is that the plant value upon which a fair return must be earned is the present cost of duplicating the existing plant (less depreciation) and not its actual original cost. It is not material, therefore, what the original outlay for franchise may have been, but it *is* important to know what moneys, if any, would now have to be expended to secure such a franchise. Neither are past losses or profits conclusive further than as they throw light upon probable future earnings.

The important facts in the above rulings are that the Wisconsin Commission has officially recognized the propriety of including going value in appraisals and has pointed out that it should be computed as the sum of two outlays:

First, moneys spent directly for getting business; and

Second, moneys advanced to cover losses in the earlier years of operation.

These amounts, of course, are not the sums which the plant under consideration may actually have expended, but the amounts a plant starting to-day would probably have to pay to secure sufficient business to make the plant self-supporting.

Having ascertained the present value of the physical plant, the Commission considers it proper to add to it these two amounts,

the total being the fair value at which the plant might be sold, or upon which the owners are entitled to earn a fair return.

Assuming the existence of the bare physical plant, without connections or business, what additional outlay would be necessary, under the conditions existing at the time of the appraisal, to bring its income up to a point where its losses would cease and it would begin to earn a fair return?

Legitimate expenditures to build up business would cover such items as advertising, circulars, solicitors, special rates or even free service for limited periods, free connections, plumbing at or below cost, etc. Not infrequently solicitors are paid a fixed sum per contract brought in. Such outlays would unquestionably hasten the attachment of services and thus shorten the unproductive period. For a water works it would be proper to take into consideration the present-day general knowledge and appreciation of the advantages of water under pressure, and the fact that it is now a necessity in manufacturing, commercial and domestic life. In any modern city the demand would be immediate and extensive, and the rapidity of securing business would in most cases be limited only by the ability of the working forces to install the plumbing and make the connections. At starting, the plant would have the public revenue from fire hydrants, public buildings, fountains, etc., and soon thereafter the income from a considerable number of private consumers. This would cover a large part of the operating expense, probably half or more. It then remains for the appraiser to estimate the period within which the necessary volume of business would be connected and to compute the probable losses up to that time. This is a matter calling for the trained judgment of a skilled observer. It depends upon the size of the city, the character and habits of the people, their wealth, the number of factories, breweries, railroads, etc., and the quality and quantity of other available supplies, such as wells and cisterns, and many other things.

The physical value of the existing plant is ascertained by estimating the cost of a duplicate plant and deducting depreciation, such cost including, of course, interest, administration, etc., during the construction period. Some engineers hold that as this duplicate plant could not be gotten into actual service for a considerable period, the net earnings of the existing plant during that period are properly a part of going value. The income of the existing plant being limited, however, to a "fair return," there would be no excess earnings, and, therefore, nothing to add. From this standpoint the city's right to purchase in no way affects going value.

The probable operating expense of the "starting plant" may be projected into the future with reasonable accuracy. It must, of course, include not only the ordinary expenditures for labor, fuel, supplies, etc., but also taxes, repairs, administration, interest and depreciation. The growth of income, however, is not so easily estimated, as it involves both the volume of business and the rates charged.

Income depends upon rates. A favorable schedule, not necessarily the highest, will shorten the unproductive period and thus decrease going value. Unwise rates retard growth and increase going value. Attempts to determine going value must, therefore, presuppose some basis of rates. But rate revision, directly or indirectly, is the purpose of most appraisals. To assume rates as a step towards fixing rates is to reason in a circle. What, then, shall be done?

Many appraisers assume that existing rates continue. It is argued that they furnish the only definite data available affecting income. To change them would be to enter upon the problematical. But existing rates may be either too high or too low for a fair return.

The tentative or "cut and try" method would seem much preferable. First compute income and then going value, using existing rates. If that income is more than a fair return, repeat the calculation at a lower rate. If insufficient, try a higher schedule. Continue these trials until a rate is found which will insure a fair return within a reasonable period. The going value on this schedule would seem to be the proper one.

Going value thus determined is clearly independent of whether the franchise has expired or whether the city has the right to purchase. It enters into the appraised value of the plant, just the same as any physical item, at its cost of reproduction.

It is interesting at this point to note the Wisconsin Commission's conclusion that going value may be negative, when later profits above a fair return have more than wiped out the deficits of the earlier years. Is not this a reasonable consideration for the future? Assuming a rate schedule and growth of business which would make the plant self-sustaining within a reasonable period, the normal continuation of that growth would cause the plant to earn profits which would soon offset the earlier losses and thus destroy our measure of going value. It would be within the legitimate power of the authorities to so adjust rates as to bring this about.

The author of the paper above referred to defines the going value of an existing plant as the cost of reproducing the income of that plant. He fixes its amount by computing the difference between the net results of its operation and the net results of a well-conducted " starting plant, through the time necessary to enable the starting plant to be completed and recover an income equal to that of the going plant."

The differences between these views and those now officially promulgated by the Wisconsin Commission, which, by the way, are held by many able engineers, are worthy of serious consideration.

The first difference is one of definition, Mr. Alvord holding that the income, the cost of producing which is to be estimated, is the gross income of the existing plant. The Commission's view is that an income sufficient to meet operating expenses is sufficient. Losses having ceased, further business is secured without cost. Previous losses may properly be called going value and charged to capital account. A greater income is of no interest or value to the municipality, for rates will at once be readjusted to the " fair return " basis, whether the appraisal is for sale or for rate fixing. No city could fairly be asked to pay an inflated " going value " based on an excessive income which it will immediately proceed to reduce. Existing income based on existing rates is, therefore, valueless for this purpose, and may even be misleading, as producing sometimes more, sometimes less, than a fair return.

Viewed from this standpoint, the financial history of the existing plant has only an indirect interest. It may help us to estimate the cost of operation and to form some judgment as to the time within which the starting plant will begin to earn a fair return.

The second difference between Mr. Alvord and the Commission lies in the method of computation. Nowhere does he recognize the direct expenditures for getting business already referred to. He compares the existing plant already doing business as a going concern with a similar " conceptual " plant without business, which would have to be built and put into operation. Meanwhile the business of the existing plant continues its normal growth. He concedes, however, that at some future date the starting plant will acquire an income equal to that to which the existing plant has then grown. The difference in net operating results up to this date comprise, in his opinion, the full measure of going value.

Two perplexities here confront us. The existing plant, with its prestige of years, its standing in the community, its "going value," if you please, would seem to have a permanent advantage. Having usually twenty or more years the start, ought not its continuing growth to keep it permanently ahead of the newer plant? And if there is to be forever a difference in their income, then the going value thus computed must be infinite.

If, however, the "starting plant" is assumed to grow at so rapid a rate that in a few years its income equals that of the existing plant, why should that rate of growth then suddenly drop to that of the existing plant? Will not the same conditions which have caused its previous rapid growth continue? If they do, thenceforward there would be an excess of income which would soon wipe out the earlier shortages, as has been well pointed out by the Wisconsin Commission.

A system of computing going value whose results may range all the way from zero to infinity is not pleasant to contemplate. But these difficulties vanish when the "fair return" income, and not the existing income, is taken as the basis.

The above method might fairly measure the increased worth of the existing system to a private purchaser as compared with a prospective plant without business, assuming a continuance of rates and income. But such assumption cannot be made in the case of municipalities (except where unexpired franchises exist), as the ultimate purpose of practically all investigations of this kind is rate revision. Furthermore, the *cost* of reproduction is the ruling condition, not the value of the thing reproduced, exactly as is the case with a pumping engine or any other feature of the physical plant.

Many attempts have been made to compute going value along similar lines, although but few have followed the exact definitions given. In some such comparisons interest and depreciation during the construction period have been assumed equal on the existing and starting plants, while they should not be charged against the starting plant at all. There is no depreciation prior to the start, and interest is always included in the construction account.

This, however, brings up another matter. As has been well said, it is not fair to substitute hindsight for foresight. No designer can foresee all possible contingencies; no engineer is infallible. Mistakes have always been made, and always will be. Boilers, engines, standpipes, buildings, reservoirs, purification systems, even sources of supply, have failed, necessitating re-

moval and, in some cases, abandonment of entire plants. Sometimes the city has not grown in the direction originally expected. Even the most capable and experienced designers, associated with men of the soundest business judgment, have encountered such disasters. It is a hazard of the business. If a new plant were begun to-morrow either by private parties or the municipality, this risk, in greater or lesser degree, would necessarily inhere in it.

No fair-minded appraiser, however, would include allowance for such mistakes, however unavoidable. The city cannot fairly be asked to purchase at or pay rates on values so determined. But does not the fact that the existing plant has, as it were, "sown its wild oats," has discarded its unwise and useless equipment and has demonstrated the fitness of its remaining parts, make it of more value than a new plant with that unavoidable experience still to go through?

The author confesses to some uncertainty as to just where this factor should appear, but that it is an element which should not be overlooked he is certain. For lack of a better place he suggests that it have its weight as one of the "contingencies" in fixing the percentage to be added to the cost of reproduction. In the average case, however, its value would not be large.

What should be the attitude of the conscientious appraiser towards those plants which are losing money? Has such a plant a going value? This question has been answered in all seriousness in the affirmative. It has been held that an established plant would lose less money than one with its business still being developed. Under Mr. Alvord's method the excess in loss of the "starting" over the existing plant would measure the going value. The Wisconsin Commission plan could not, of course, be applied, as the continuing losses would make the going value unlimited. Under these circumstances there may be several views:

1. A study of the situation may show that the normal growth of the business will soon end the losses.

2. The losses may be decreased, and in due time ended, by some reasonable advance in rates. In both of these cases the Wisconsin rule could safely be applied.

3. If, however, the situation is such that there appears to be no reasonable way to make the plant earn a fair return, the solution becomes complex.

Such cases, unfortunately, are not uncommon, particularly in smaller cities and in undeveloped or boom territory.

Sometimes both the city and the owners have been over-sanguine as to the future. Many cities have in times of enthusiasm and prosperity been induced by energetic promoters to enter into contracts for service which have later proved exceedingly unwise for all parties concerned. Business has not developed, nor has the place grown as anticipated. Important industries may have ceased; opposition towns or railroads may have taken the business away.

While the plant is losing money at the existing rates, it is nearly always true that these rates, both public and private, are a serious strain on the limited resources of the city and its people. No advance is, therefore, possible; it may even be impossible to maintain existing rates. Not infrequently the expiration of the contract is looked forward to as a date when relief may be expected.

Such contracts are usually for periods of twenty to thirty years. Usually all obligations between the parties end with the expiration of the contract. There seems no escape from the conclusion that the owners of the plant must accept the situation as it then exists. As they would have been entitled to the profits of a successful plant, so also must they accept the losses of the unprofitable one. If the cost of service is beyond its means, the city is at liberty to discontinue it. If the contract made no provision for extensions, or if such provisions were illegal, the plant has no rights superior to those of the municipality. It is to be presumed that the owners knowingly took the risk of securing, within the contract period, such returns as were necessary.

This view is, of course, hard on the invested capital, but the law very wisely prohibits municipalities from incurring obligations which may prove onerous to future generations. Posterity should not be made to suffer through the errors of earlier days. In some cases it has been held that, owing to the uncertainties attending the situation at the end of the contract, the "fair return" basis entitled the owners to rates which would make the earnings sufficient to retire the entire investment, less scrap value, within the contract period. This interpretation, however, is very rare. It has a counterpart in those states which require the establishment of sinking funds by municipally owned plants to retire the bond issue within a definite period, usually much less than the life of the plant.

The problem then is, not whether a going value should be included in the value of the plant, but to determine a value

which the maximum income possible under the existing circumstances will support. In other words, the actual worth of the service to the community fixes a limit to the value of the plant, beyond which no figures, however elaborate or logical, can go.

Under a strict interpretation of either the Alvord or the Wisconsin theory, the city would be required to purchase the plant at a valuation, or pay rates giving a fair return on a valuation, based on cost of duplication less depreciation plus going value. The latter, on account of the slow building up of the business, would be large.

Clearly, however, this would be unfair to the city, as involving prohibitory rates, rates which the public service could not stand, and which would discourage private consumption and prohibit growth, thus minimizing private revenue. The difference could not be made up by increased taxation, as this is limited by law.

We may, of course, take the broad stand that if a city wants water works it must pay the price; they cannot be run as charitable institutions. But there is a limit to the city's ability to pay. Is it not true, therefore, that the plant, in order to continue to serve the community, must be willing to adjust its rates to a basis which the people can pay? Would not any other course necessarily end in forcing the city to discontinue a service beyond its means, a result disastrous to all concerned?

Evidently the construction of a plant at all in such a location was a mistake on both sides. Is it not the clear duty of the appraiser in such cases to eliminate, on the one hand, every possible element of questionable value and to get his figures down to bed rock, in the hope of finding a way to meet the exigencies of the situation, and, on the other hand, to see that the city acts in equal good faith, that it properly appreciates the full value of a good supply and apportions the maximum amount possible to that service? It is worth remembering that in many cases the lowering of private rates to points originally considered suicidal has so attracted consumers as to materially increase both gross and net income.

Evidently in such unfortunate cases the situation demands a valuation quite apart from the actual physical plus the going values, however just those values may be in the abstract. Fairness to the municipality is not less essential than fairness to the plant. The courts have decided that while such regulations are intended to be mutually fair, they must in any event be fair to the city.

Clearly such reasoning is only effective when the city is prepared for the alternative of abandoning the service. If it is so situated that it cannot do without the service, then it must find a way to pay a fair return for it. But in no event can the value of such a service exceed the cost of getting that service in some other way.

Further perplexities are often found. It has been questioned by many fair-minded men whether the plant, after all, has any ownership of the business on which going value is based. Should the people pay for what they have themselves furnished? Certainly such value can go no further than the actual cost of reproducing that business.

It will be noticed that both the Alvord and Wisconsin methods give the greatest going value to those plants which have had the longest and hardest struggles to build up their business, while such plants are actually worth the least as commercial propositions. Prosperous plants, with large business quickly established, have the least going value, though far more attractive to the investor. The same is true as regards rates. A high schedule usually means low going value, while low rates increase going value.

With such wide divergencies of opinion among thoughtful and fair-minded men, it is not strange that much effort has been devoted to the finding of better and simpler methods. Nor is it strange that, despairing of success, shorter methods, less logical, perhaps, but giving due recognition to the underlying principle, should find favor. Some of these may be noted:

In one of the most important cases of recent years, in the hands of men of great ability, the results of various methods of computation were all found to be reasonably close to one year's gross revenue, and that sum was finally agreed upon.

In the recent Staten Island case * the going value was arbitrarily fixed at $10 per service.

In Canada a flat addition of 10 per cent. is made to the physical value to cover all the intangible values. See Municipal Acts of Ontario, third edition, VII, chapter 19, section 566, subsection 4, clause (a2), which reads:

"In any arbitration under Clause (a) hereof to determine the price to be paid for the works and property of a gas or water company, the arbitrators shall determine the actual value of

* "Acquisition by New York City of the Larger Two-Water Systems of Staten Island," by L. L. Tribus, Milwaukee meeting, American Water Works Association, June, 1909.

such works and property, having regard to what the same would cost if the works should be then constructed or the property then bought, making due allowance for deterioration and wear and tear, and making all other proper allowances, but not allowing anything for prospective profits or franchise, and shall increase the amount so ascertained by 10 per cent. thereof, and such increased amount shall be the amount which the arbitrator or arbitrators shall award as the price to be allowed for the said works and property."

In drawing a new water contract at Mexico, Mo., the author recently adopted a somewhat similar idea, as follows:

"PURCHASE BY CITY. The city shall have the right to acquire by purchase all the property of the grantee actually used and useful for the convenience of the public at any time after the expiration of fifteen (15) years from the passage and approval of this ordinance by public vote, upon giving one year's notice to the grantee and upon paying therefor in cash the then cost of duplication, less depreciation of said property, with ten per cent. (10 per cent.) additional thereto as compensation for earning power, franchise value, going value, contingencies and all other intangible values of every nature whatsoever."

Mr. Alvord's concluding remarks indicate a preference for using the actual cost of the existing plant, where it can be ascertained, as the basis of fixing rates, rather than the present cost of reproduction less depreciation, because of the exceeding complexity of the computations. It may be questioned whether many appraisers will follow him here. The idea is fundamental that present values and rates must be based on present-day conditions. Nor is it usually difficult for able, experienced and fair-minded appraisers to agree with reasonable closeness on physical values.

When the intangible values are taken up, the situation, as has been shown, is far different. Here, if anywhere, simple and direct methods, appealing more strongly to the average man's ideas of fairness, are needed. And from this standpoint the simple methods used above are not without merit.

[NOTE. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by January 1, 1910, for publication in a subsequent number of the JOURNAL.]

JULIUS WILLIAM SCHAUB. A MEMORIAL.

By Edward Flad, Member of the Engineers' Club of St. Louis.

[Read before the Club, October 6, 1909.]

Julius William Schaub was born in St. Louis, Mo., on September 23, 1859. He was the only son of Henry Schaub and Susan Orb, both of whom were born in Germany. His death occurred March 30, 1909. He had been suffering from ill health for several years and had taken a rest cure and treatment at Muldoon's Sanitarium at White Plains, N. Y., from which he appeared to derive much benefit. A second visit to the same sanitarium resulted in a firm conviction on his part that he was doomed to remain an invalid. After a stay of about a week at the sanitarium he wrote to his wife, who was at their home in Chicago, to expect him home on the afternoon of March 30. While on his return trip on the fast west-bound Michigan Central Train No. 9, he came to his death in the toilet room of the car in which he was traveling. His dead body, with a revolver on the floor by his side, was discovered by the train porter just after the train left Kalamazoo, Mich. He had last been seen alive when the train passed through Battle Creek, Mich.

Schaub received his early education in the public schools at St. Louis, entered Washington University, St. Louis, in 1878, and graduated from that institution with the degree of Civil Engineer in 1881.

For his graduation thesis Schaub selected the subject, "The St. Charles Bridge." I remember being one of the boys who went to St. Charles in charge of Prof. Charles A. Smith to measure up the details of the bridge and obtain material for Schaub's thesis. He was a good worker as a student, and early displayed those qualities of close application to the problem in hand and interest in his work which in after years brought him recognition in his chosen profession.

Schaub's first employment was in the office of Col. C. Shaler Smith at St. Louis. Shaler Smith had designed the St. Charles Bridge and was one of the foremost bridge engineers of that time. Here Schaub obtained his first practical lessons in bridge designing and bridge construction.

In the spring of 1882 Schaub was sent by Shaler Smith to

the Edgmoor Iron Works, near Wilmington, Del., as inspector on bridge-work. He retained that position for two or three years. His shop training at the university had especially fitted him for inspection work and he received unusual consideration from shop men, who had grown accustomed to the inspection of engineering graduates who had had no shop experience.

He remained with C. Shaler Smith from 1881 to 1886. From 1887 to 1892 he was chief engineer of the Detroit Bridge and Iron Works. His fairness and generosity are well illustrated by an account by George H. Pegram of a meeting with Schaub in the fall of 1888, when Schaub was chief engineer of the Detroit Bridge and Iron Works. Pegram writes as follows:

"I had obtained a price from the Edgmoor Iron Company to enable me to make a tender on my patented bridge to the Missouri Pacific Railway, and stopped off at Detroit to see Schaub on my way to St. Louis. When I showed him my plan and the tender I was going to present, he laughed and told me that they were going to bid for the same bridge at a considerably lower figure, with a fair chance of getting the work. I then asked him to give me figures on my plan, making a fair comparison with his own, that I might use in competition. He gave me a price less than his own, contending that the cost of shop work, etc., was much cheaper on my plan. I bid on the bridge and got the contract, which otherwise would have gone to them, as they were the next highest bidder. I have never received more generous and noble treatment."

In 1893 Schaub became chief engineer and manager of the Pottsville Iron and Steel Company, and from 1895 to 1897 he held a similar position with the Hamilton Bridge Works, of Hamilton, Ont., Canada.

In 1898 he established an office in Chicago as consulting engineer, being engaged largely in bridge and structural steel work, serving in this capacity a number of important railways. With the development of reinforced concrete he devoted considerable attention to the use of this material for structural purposes. He had patented a reinforced concrete caisson system for deep foundations (noted below) and a floor system in which each panel acted as a groined arch. He had designed also a reinforced concrete roadbed for railways, with modifications for use on bridges and in tunnels, and this was described by him in *Engineering News*, November 2, 1905.

In 1900 he was engaged by the St. Louis & Southwestern Railway to report upon its bridges. He made a personal examination of every bridge on the system, and prepared plans for

the strengthening necessary to adapt the bridges to the increased loads. In 1903 this railway took over a narrow-gage road in Arkansas which had a bridge crossing the White River at Clarendon, Ark. There was some question as to the stability of the cylinder piers under the increased loading, as there was no information as to their penetration. The method of strengthening devised and carried out by Schaub was to surround each old pier with a concrete caisson which was sunk to a greater depth than the old cylinders and became a part of the new pier. The two rest piers (for two fixed spans) consisted each of a pair of 6-ft. cylinders; both cylinders were inclosed in a new rectangular caisson about 12 by 38 ft. The pivot pier of the 355 ft. swing span had six 4-ft. cylinders arranged in the form of a hexagon, and a central 6-ft. cylinder; these were all included in a 33-ft. circular caisson of reinforced concrete 18 in. thick. The space within the rectangular caissons was filled with concrete, but that within the circular caisson was filled with sand.

Schaub was consulting engineer also for the new bridge of the same railway crossing the Red River at Shreveport, La., including both the substructure and the superstructure. This was commenced in 1904 and completed in March, 1907. It has four fixed spans of 200 ft., one of 150 ft. and a swing span of 300 ft. One of the notable features of this work was that the pier foundations were sunk to depths of from 60 ft. to 80 ft. by open cofferdams of reinforced concrete, on Schaub's patented system. He did a considerable amount of work for Mr. H. G. Kelly, member American Society of Civil Engineers, while the latter was chief engineer of the Minneapolis & St. Louis Railway, and later when he became chief engineer of the Grand Trunk Railway. One of Schaub's latest works was the design of a very large swing-bridge for the Grand Trunk Railway at Black Rock Harbor, Buffalo, N. Y., to form a part of the International Bridge. This will have a length of 451 ft. 5 in., and will carry two railway tracks and two roadways; it will be operated by electric power.

His work was not entirely in the line of bridges, however. In 1901 he was consulting engineer for the St. Louis, Iron Mountain & Southern Railway in connection with the design and construction of its new shops at Little Rock, Ark. In 1903 he had a similar engagement with the Missouri Pacific Railway for its extensive locomotive and car shops at Sedalia, Mo.; the plant included some fifteen or sixteen buildings, with a machine and erecting shop 752 by 135 ft.

Schaub became a junior of the American Society of Civil

Engineers in 1884, and was elected a member in 1886. He was a non-resident member of the Engineers' Club of St. Louis from 1888 to 1905. He became a member of the Western Society of Engineers in 1902. He was a member also of the American Railway Engineering and Maintenance of Way Association, and of the Engineers' Club of Chicago. He wrote a number of papers for engineering societies and the technical papers, and took part also in many discussions on matters relating to his particular lines of study. His name has appeared many times in the *Engineering News* in connection with articles and letters. Some of his writings are: "The Detroit Union Depot Viaduct," Transactions of the American Society of Civil Engineers, May, 1893; "Proposed Specifications for Railway Bridges," Proceedings of the Western Society of Engineers, October, 1900 (and *Engineering News*, October 11, 1900); "Diagram for Obtaining the Percentage of Steel and Moment of Resistance of Reinforced Concrete Beams," *Engineering News*, April 30, 1903; "Some Phenomena of the Adhesion of Steel and Concrete" (from a lecture delivered at the Armour Institute of Technology), *Engineering News*, June 16, 1904; "Concrete Floors for Railway Bridges and Tracks," *Engineering News*, November 2, 1905; "The Railway Track of the Past and Its Possible Development in the Future," *Journal of the Western Society of Engineers*, May, 1907 (and *Engineering News*, June 13, 1907).

In 1893 Schaub was married to Miss Harriet Holmes, of Lock Haven, Penn. No children resulted from the union. His wife and his sister (Mrs. Emma Rauch, of St. Louis) survive him.

Schaub was a genial man, of a sociable disposition, and devoted to his friends. He had marked ability as an engineer and was not content to follow along in the well-beaten paths of his profession, but led the way to new methods and advanced ideas in the design of the works on which he was engaged.

His friends mourn his death, the loss of his friendly greeting and ready sympathy. The profession suffers a distinct loss in the untimely taking away of an engineer of high ideals, of broad experiences and brilliant attainments.

OBITUARY.

Arthur Ward Hunking.

Member, Boston Society of Civil Engineers.

Arthur Ward Hunking, the only child of Elihu and Elizabeth Smith (Nash) Hunking, was born in Haverhill, Mass., September 1, 1851, and died at Helena, Mont., November 12, 1908. Losing his own mother a few days after his birth, he knew for his earliest recollection a mother's care in the person of his stepmother, Esther (McCurdy) Hunking, who came to his home and nurtured him when he was about two years old. He was cared for in his days of infancy by his aunt, Amelia Baker, his father's sister.

He spent his childhood and young manhood in the city of Haverhill, attending the public schools and graduating from the high school with the class of 1868, "a large and talented class."

His father, in company with his uncle, was a prosperous shoe manufacturer before and during the Civil War times, and Arthur, as a lad, was more or less acquainted with successful shoe-shop work and methods, and was of considerable help and "quite handy" at odd times and during vacations. Here he doubtless acquired or developed the habits of system and organization in the management of business which he exhibited to considerable advantage in later years.

Upon graduating from high school, he entered the civil engineering course at the Massachusetts Institute of Technology, joining the class of 1872, and continuing as a special student for the years 1868–69, 1869–70, and 1870–71.

Soon after leaving the Institute he was for several years engaged in general engineering with Clemens Herschel, C. E., first at the office near the head of State Street in Boston, and later his name appeared on a sign in connection with Mr. Herschel's, on Bartlett's Building, opposite the railroad station at Green Street, Jamaica Plain, where Mr. Herschel had for some years resided, and where he and young Mr. Hunking had good prospects of establishing a surveying and engineering business that would develop with the growing community.

It was here and at this time that Mr. Hunking, with the brightest prospects of youth and ability before him, met with a

sudden and almost overwhelming misfortune that affected his life for many years and quenched his courage to continue the office and work at Jamaica Plain. He had married, in 1873, Miss Ella F. Thacher, of Haverhill, formerly of Sacramento, Cal.; had started housekeeping in the pleasant village of Jamaica Plain, and had been blessed with a little boy, Arthur R., when, hardly more than a week after the son's birth, the mother was taken away with quick consumption, leaving him alone with the infant son, who survived his mother but a little more than a year, dying at the grandparents' home in Haverhill in January, 1875.

During these years of service with Mr. Herschel, Mr. Hunking was earning a reputation in business which rated him in quoted words "as eminently trustworthy and faithful."

After a year or so of general engineering work on several small jobs in the neighborhood of Haverhill, he having returned to his father's roof after the breaking up of the home at Jamaica Plain, Mr. Hunking, in May, 1876, came to the office of the Proprietors of the Locks and Canals on Merrimac River in Lowell as an assistant engineer under Mr. James B. Francis, and entered into the work of that concern with interest and enthusiasm.

He learned the various methods and principles of that master hydraulician, and proved an efficient assistant in the many duties of the place.

Besides posting himself on the measurement and management of the distribution of the water of the river-flow, which is the principal duty of the water power company here, Mr. Hunking applied himself to the problems of fire-protection and took a prominent part in the design and installation of the systems of perforated pipe sprinklers then in very general vogue in the mills of Lowell. Brief accounts of the details of the system may be found in the *Franklin Institute Journal*, April, 1865, and August, 1878, the latter article being by the pen of J. P. Frizell, C. E., under whom Mr. Hunking spent several weeks to familiarize himself with the application of the mathematics and graphics of the problem.

While busy in this and in kindred lines of engineering at Lowell, Mr. Hunking became exposed to an attack of the Leadville fever, which was spreading in violence over the East, and which located three cases in the Locks and Canals office. Mr. Hunking, feeling that a wider opening and broader prospects awaited him in the far West, determined to try his chances for them.

Having married, in January, 1880, Miss Sarah F. Parker, of Chelmsford, an old-time playmate of his, he, a month later, started for Leadville in company with Edmund S. Davis and Arthur I. Fonda, engineer companions from the Locks and Canals office. He found occupation at once in the office of Stowell & Frank, United States deputy mineral surveyors in Leadville, where he stayed about three months surveying mining claims in the vicinity, his wife meanwhile, at her father's home in Chelmsford, awaiting his settling down permanently before following him.

But his former employer and partner, Mr. Herschel, finding that he had cut loose from the Locks and Canals Company, and being in especial want of just such a "faithful and trustworthy assistant" as he knew him to be, and because his experience at Lowell had further fitted him for the particular position he had in mind, persuaded him to return East and take the office of principal assistant hydraulic engineer under him at the Holyoke Water Power Company.

The company here had just started to reorganize its methods of measuring and distributing the water-power of the Connecticut River to the various mills and manufactories holding rights or privileges of different kinds to the river flow, and Mr. Hunking was just the man to adapt and apply there the methods and system which had been so thoroughly worked out and experimented with at Lowell.

Having determined the capacities of the numerous water wheels of the mills, and the quantities of water used in other manners, they inaugurated a system of water-wheel measurements and a scheme of distribution which received the unqualified approval of the superior officers of the company and its customers for water power and water privileges.

He was not to remain here long, however, for before the fall had fairly commenced he was prevailed upon by Mr. James B. Francis, of the Locks and Canals Company, to return to Lowell to its employ and assume the charge of the hydraulic part of its work, so that Colonel Francis, the principal assistant engineer, could devote himself mainly to the land business of the corporation, which had then grown to considerable dimensions and was in great need of rearrangement and systematizing.

Mr. Hunking reëntered upon the work for the Locks and Canals with earnestness and enthusiasm, and maintained the same order, system and efficiency that the older Mr. Francis had inaugurated years before.

In 1883, while managing the experiment on the Humphrey turbine water wheel at the Tremont and Suffolk mills in Lowell, and the subsequent experiments on the flow of water over submerged weirs, under the direction of Mr. J. B. Francis, who depended upon him in a very large measure for the accuracy and elaborateness of the tests, Mr. Hunking, coincidently with an assistant, became impressed with the possibility of avoiding a large part of the seemingly necessary work in calculating the weir quantities by the standard Francis formula, adapted for a considerable velocity of approach, and both he and his assistant, by different methods of reasoning, arrived independently and without knowledge of each other's meditations at the conclusion that the velocity-of-approach correction in the above-mentioned formula was a definite and simple function of the relative proportion between the areas of water section at the crest of the weir and at the point of observation of the depths of flow over the weir.

A casual remark of the assistant encouraged Mr. Hunking to work out his ideas, and the labors of the two were combined, condensed and finally published by him in the *Franklin Institute Journal* in August, 1884.

Mr. Hunking's thoroughness in the treatment of work is exhibited in this short article, for he not only gives a refined mathematical formula, but he adds a table, suggests a curve, offers a close approximation easily calculated, and ends with a roughly approximate method (quite inside the limits of practice) that may be worked out mentally. His examples, quoted at the close, finish his argument and the case.

In January, 1885, Mr. Hunking was elected principal assistant engineer by the directors of the Proprietors of the Locks and Canals, his predecessor, Colonel Francis, taking the position of chief engineer and agent, and the senior Mr. Francis, who had then served the Proprietors for fifty years, most of the time as agent and engineer, was made consulting engineer, and was considerably relieved of much of the routine responsibilities which he had previously so acceptably borne.

When the serious and disabling accident in 1888 befell Colonel Francis, and much doubt was in all minds as to his chances of recovery, Mr. Hunking took a great part of his duties, ably seconding the consulting engineer, who stood ready, if necessary, to take up the duties he had laid off a few years previously. The fact that his father had such an able assistant to share the work greatly eased the mind of Colonel Francis during his protracted disability and convalescence.

Later, when Colonel Francis was at work on a scheme for the rearrangement and adjustment of the water-power, rights, uses and privileges on the Concord River at Whipples' Falls, Lowell, which had been involved in lengthy lawsuits, the problem having been given to him by the court to straighten out, he found in Mr. Hunking an assistant of great help and valued counsel, upon whom he relied for much of his measurements and conclusions.

Meanwhile Mr. Hunking was approached by those who had interests and opportunities in water-power management or development, but though he gave them due consideration, yet for one reason or another no change was decided upon. In some of the cases it may have been that the persons having in charge the management of the enterprises, being friends of Mr. Francis, felt unwilling to take from him, without his freest consent, his most valued and indispensable assistant.

However, after Mr. Hunking had managed a very acceptable experimental test of one of a set of six Victor turbines for the Tremont and Suffolk mills, in 1890, the Stillwell & Bierce Company, makers of the turbines, being very much pleased with his ability and the straightforwardness of his management, concluded that they had found a man that they wanted and made him an offer to go into their turbine wheel department. He accepted, and after a few months spent at their shops in Dayton, Ohio, making himself acquainted with their methods and the details of the work, he took the field, visited the mills and sites for projected water wheel installations, studied their particular needs, and made designs and estimates for putting in the plant called for. In the spring of 1893 he was on hand near Fresno, Cal., with a proposition for ten pairs of Victor wheels of 133 h. p. each (an aggregate of 2 660 h. p.) to provide pumping power for the Sunset Irrigation District, for watering 300 000 acres on Kings River, Fresno County.

In June, 1893, he left the employ of the water wheel concern to take a position with the Philadelphia Manufacturers Mutual Fire Insurance Company.

In January, 1895, at the strong recommendation of Colonel Francis, he was engaged by parties interested in and connected with the Massachusetts Cotton Mills, of Lowell, to supervise the erection of the first mill of the "Massachusetts Mills in Georgia," at Lindale, near Rome, and after its erection and fitting out he continued in charge of the work of manufacturing, as agent and general manager, until February, 1899.

A few months later he took charge of the erection of the Merrimac Manufacturing Company's first mill at Huntsville, Ala., and continued there for about two years.

Later he was the resident engineer for the Greenfield Electric Light Company, developing its water-powers on the Deerfield River at West Deerfield and Shelburne Falls. He commenced the work at West Deerfield July 2, 1902. After making soundings and doing some preliminary work, this site was abandoned, as satisfactory foundations would be too costly. On August 1, 1903, the work of developing the power at Shelburne Falls was commenced under his supervision, and completed in October, 1904.

In March, 1905, he was employed by the Stone & Webster Engineering Corporation as resident hydraulic engineer on a large concrete dam about to be built across the river at St. Croix Falls, Wis. He remained there about a year, when he was transferred to take charge of surveys for an important work at Columbus, Ga., a dam across the Chattahoochee River, where much especially difficult work was called for on account of the character of the country, which required the careful consideration of several proposed locations.

In July, 1908, he was appointed hydraulic engineer of the Stone & Webster Corporation in charge of the reconstruction of the noted Hauser Lake dam, near Helena, Mont., and was actively engaged in this undertaking at the time of his death, which came suddenly.

His illness began on Sunday, November 8, and was apparently slight for a few days, but by Wednesday serious fears were excited, and he passed away Thursday, November 12. His only son, Mr. Sidney H. Hunking, also engaged by the Stone & Webster Company on the Hauser Lake work, was able to be with his father during his last days.

Mr. Hunking leaves a wife, a son, above mentioned, and a daughter, Miss Blanche B. Hunking.

He was a Knight Templar, a member of Masonic orders in St. Croix Falls, Wis., and in Columbus, Ga., and the Masonic Club of Lowell. He was a member of the Montana Club, Helena, and of the New England Water Works Association.

His membership with our Society dates from May 30, 1885. His only contribution to the literature of our society is the paper on "Water Power Equipment," read in November and December, 1893.

Mr. Hunking, on account of conditions of residence and

work, was not particularly well known to the greater portion of our members, especially those of the younger generation, and as he was of a quiet and reserved disposition, not many of the older members outside of the water works and hydraulic practice were likely to meet him and form his acquaintance. Those who have met him and known him will not be surprised at some of the high testimonials that the writer has received in answer to inquiries for data and information for the compiling of this memoir.

The writer feels the most positive assurance that, were Mr. Francis, Senior, and Colonel Francis alive, each would express the highest testimonials to Mr. Hunking's character and ability.

His last employers say that "his work while with us was always thorough and accurate, and the respect and esteem in which he was held by all with whom he came in contact was constantly growing," and "he had rendered services and formed associations of a character to make his loss keenly felt."

And from those who worked under him the writer has personally received many expressions of cordial appreciation of his dealings with them which only the truly kind, considerate and unselfish employer can expect to receive and be worthy of.

These latter testimonials can be summed up in no better shape than by quoting from a brother engineer, not a member of our Society, one who has had long and close acquaintance with Mr. Hunking.

He writes as follows:

"For more than thirty years Mr. Hunking was my friend, and I was perhaps nearer to him than any other man. I usually saw him whenever he came home, and in all my acquaintance with him I always found him to be cordial, polite, thoughtful and unselfish, a man whose friendship was worth having.

"He was a man of such dignity that he always expressed himself in plain English, in a manner that was simple, lucid and forceful, with none of the embellishments of vulgarity or profanity such as many smaller men seem to think necessary.

"He was a skillful engineer, and, what is vastly more important, he was a gentleman."

Frank S. Hart, *Committee.*

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REFUSE DISPOSAL, AND THE NEW REFUSE INCINERATION PLANT FOR MILWAUKEE.

BY SAMUEL A. GREELEY, RESIDENT ENGINEER.

[Read before the Engineers' Society of Milwaukee, May 12, 1909.]

IN December, 1907, Mr. Rudolph Hering, consulting engineer, presented a report to the mayor and common council of the city of Milwaukee dealing with the problem of the disposal of the refuse of the city. This report presented data relative to the quantity and character of the refuse, and fully discussed the various methods of refuse disposal. Based on the investigations described in the report, Mr. Hering recommended "as a first installment a plant capable of incinerating 300 tons daily, costing $200 000."

This report was accepted by the city council, and Mr. Hering was engaged to prepare plans and specifications for the work. Bids were called for in accordance with these plans and specifications, and on April 3, 1909, the contract for a 300-ton refuse incineration plant was awarded to the Power Specialty Company of New York. Their contract with the city includes the excavation, piling, concrete, furnaces, boilers, flues, cranes and machinery for the plant. It does not include the chimney or the superstructure for the plant, these parts of the work having been let under separate contracts. The total amount of all the contracts foots up to slightly less than $200 000. The actual work of construction is now under way. Hering and Fuller, Consulting Engineers, 170 Broadway, New York City, have been engaged by the city to supervise the construction of the plant. It is

expected that the plant will be in operation early in the spring of 1910.

The purpose of the plant is to burn refuse completely, without nuisance and at an average temperature of 1 500 degrees fahr. The design and development of such a plant fundamentally involve some knowledge of the character of the material to be burned.

According to the specifications, refuse is defined as being a mixture of garbage, ashes, rubbish, manure and small dead animals. These are the chief constituents of city refuse. The composition and character of such refuse varies from season to season, and even from day to day. Nevertheless, limiting conditions may be determined which control the design. Thus in winter, when the percentage of ashes in the refuse is high, the clinker produced in burning the refuse will be the greatest, and its handling will be most difficult. In the summer, on the other hand, the clinkering will be easier work, but the maintenance of a high temperature will be difficult, on account of the high proportion of wet garbage in the refuse. The rate of combustion will be low, and the capacity of the plant will be based on summer conditions. Following are the compositions of ashes, manure, garbage and rubbish as they were used in working out the plans for this work. They are briefly compared with analyses determined elsewhere.

Ashes.

Ashes are either steam ashes, such as come from large boiler plants, or are household ashes. They contain about 15 per cent. of water, 10 per cent. of volatile matter, 50 per cent. of true ash and 25 per cent. of carbon. Ashes analyzed in Pittsburg, for a report by Mr. Hering, contained on the average 7 per cent. of water, 10 per cent. of volatile matter, 58 per cent. of true ash and 25 per cent. of carbon. The average chemical analysis of ashes given in the "Report of Commission on Street Cleaning and Waste Disposal, the City of New York, 1907," is 27 per cent. of water, 8 per cent. of volatile matter, 53 per cent. of true ash and 18 per cent. of carbon. This ash contains a rather high percentage of water. The calorific value of ashes is about 3 700 B.t.u. per pound.

Manure.

Manure is the cleanings from stables. I know of no chemical analysis of manure. In El Paso, Tex., it has been used as a fuel under boilers. It has been assumed that it contains 40 per

cent. of water, 25 per cent. of volatile matter, 15 per cent. of true ash and 20 per cent. of carbon. One of the bidders for the work here based his guarantee for temperature and evaporation on a composition of 70 per cent. water, 13 per cent. of volatile matter, 4 per cent. of true ash and 13 per cent. carbon. The calorific value of manure is, therefore, about 2 700 B.t.u. per pound.

Garbage.

Garbage is the waste from kitchens, restaurants, butcher shops, hotels, etc. It has been chemically analyzed in Milwaukee and in several other places. The results of the analysis in Milwaukee were 78 per cent. of water, 14 per cent. of ash and 8 per cent. of combustible. Analyses made in New York by the Commission on Street Cleaning gave an average chemical content of 69 per cent. water, 22 per cent. volatile matter, 5 per cent. ash and 4 per cent. carbon. The tests made by Mr. J. T. Fetherstone at West New Brighton, N. Y., showed an average composition of 73 per cent. water, 17 per cent. volatile matter, 5 per cent. ash and 5 per cent. carbon. The calorific value is not far from 2 000 B.t.u. per pound.

Rubbish.

Rubbish contains papers, wood, rags, bedding, leather, glass, metals, sweepings from stores and offices, and litter of a similar nature. The composition taken for Milwaukee is 15 per cent. of water, 45 per cent. volatile matter, 15 per cent. ash and 25 per cent. carbon. One of the bidders for the work at Milwaukee assumed a composition of 8 per cent. water, 38 per cent. volatile matter, 14 per cent. ash and 40 per cent. carbon. Tests by Mr. Fetherstone at West New Brighton gave an average composition of 6 per cent. water, 65 per cent. volatile matter, 14 per cent. ash and 15 per cent. carbon. Analyses made by the Commission on Street Cleaning of New York gave 12 per cent. water, 40 per cent. volatile matter, 8 per cent. ash and 40 per cent. carbon. The calorific value of rubbish may vary from 5 000 B.t.u. to 7 500 B.t.u. per pound.

Refuse.

The mixture of these component parts and of small dead animals is defined as refuse. The proportions in which these components enter into the mass of refuse have been carefully measured and are given for the various seasons in the following table:

TABLE 1.

	Summer. Per Cent.	Winter. Per Cent.	Average for Year. Per Cent.
Garbage	57	31	41
Ashes	30	60	41
Rubbish	5	6	5
Manure	8	3	13
	100	100	100

The proportions are all given by weight. If we combine these percentage proportions with the chemical composition of each component already given, we get the following composition of refuse for summer, winter and for the average throughout the year:

TABLE 2.

	Summer. Per Cent.	Winter. Per Cent.	Average for Year. Per Cent.
Water	53	35	43
Volatile matter	13	11	11
Ash	20	35	30
Carbon	14	19	16
Total	100	100	100
B.t.u. per pound	2 850	3 350	3 120

If we reduce Table 2 to pounds per ton we get the following values:

TABLE 3.

	Summer. Pounds.	Winter. Pounds.	Average for Year. Pounds.
Water	1 060	700	860
Volatile matter	260	220	220
Ash	400	700	600
Carbon	280	380	320
	2 000	2 000	2 000

The successful bidder for the Milwaukee work based his guarantee on the chemical composition given in the following table. These percentages, as elsewhere, are given by weight of the wet material as collected.

TABLE 4.

	Summer. Per Cent.	Winter. Per Cent.	Average for Year. Per Cent.
Water	45.2	25.2	35.0
Volatile matter	18.2	12.7	18.7
Ash	26.8	41.5	30.6
Carbon	9.8	20.6	15.7
Total	100.0	100.0	100.0
B.t.u. per pound	3 134	3 900	3 475

Such, then, is the character of the refuse to be burned in the new incinerator. The quantity will be 300 tons per day. This will be made up of garbage from the whole city, and of the ashes and rubbish from wards 1 to 7 inclusive, together with sufficient manure to make up the total quantity. The quantity of small dead animals will not exceed one ton per day. The proportion of garbage in the refuse is, therefore, unusually high and does not represent the true average proportion for the whole city. Eventually, if other incinerators are built, so that all of the ashes and rubbish of the city, as well as all of the garbage, can be burned, the proportion of garbage will be lowered, and the calorific value of the refuse will be correspondingly increased.

Methods of Disposal.

There are several methods of refuse disposal, such as by dumping on the land or at sea, by burial in suitable soil, by feeding to swine, by reduction or by incineration.

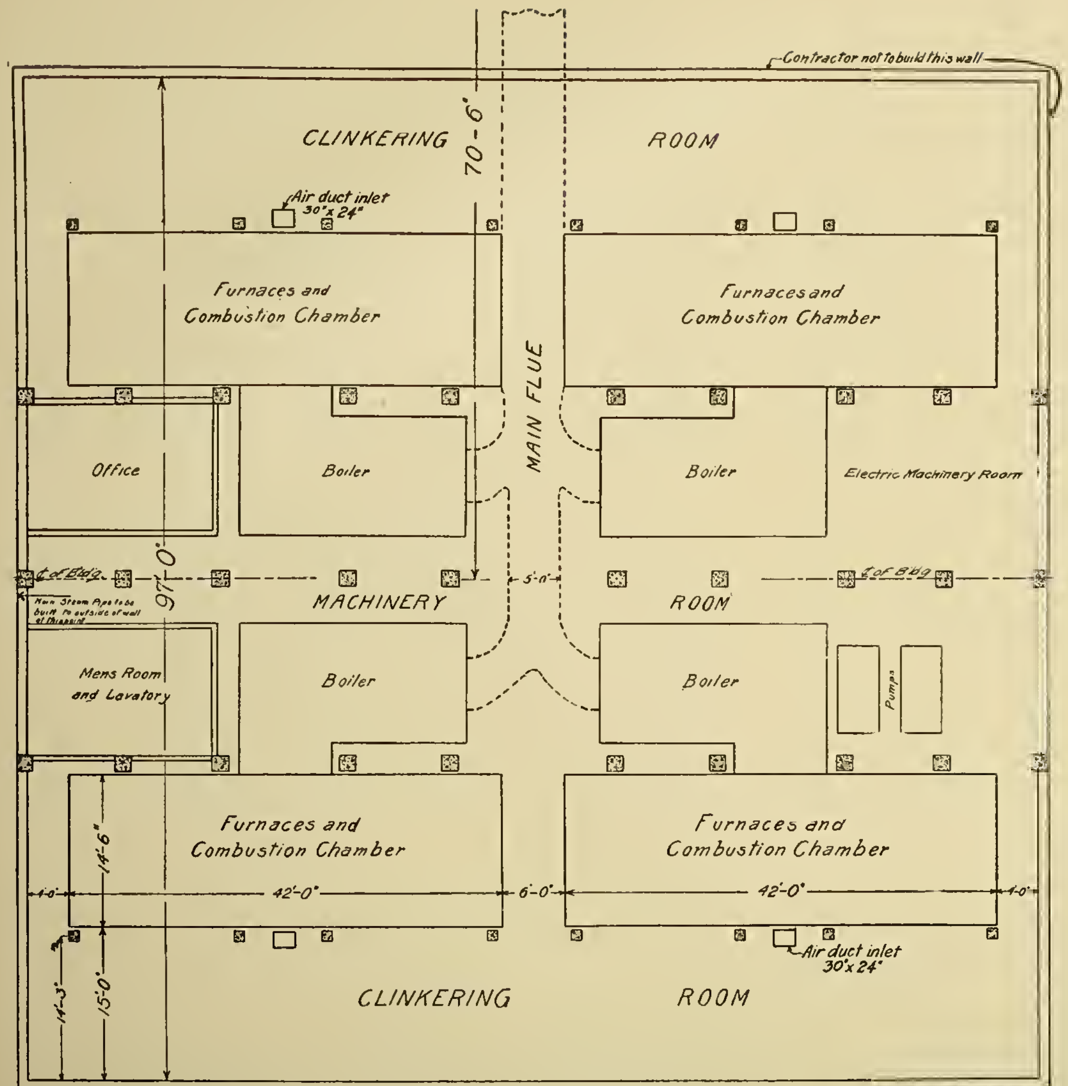
Ashes and rubbish are very often dumped on waste land within convenient hauling distance, as is done in your own city and in Chicago. This is dangerous to health, because germs of disease from sick rooms and hospitals may be lodged in the cast-off clothing and bedding, in the rubbish, and may be spread by the wind, by flies or otherwise. Such rubbish should be burned.

Dumping at sea or in the lake has been practiced in Milwaukee, but has never been favored as a permanent method of disposal. In New York City a portion of the garbage is dumped at sea.

Burial in the soil may satisfactorily dispose of garbage. Too often, however, the garbage is not buried, but is only spread out upon the ground surface to rot and create obnoxious odors. In York, Penn., such odors were objectionable at a distance of one mile.

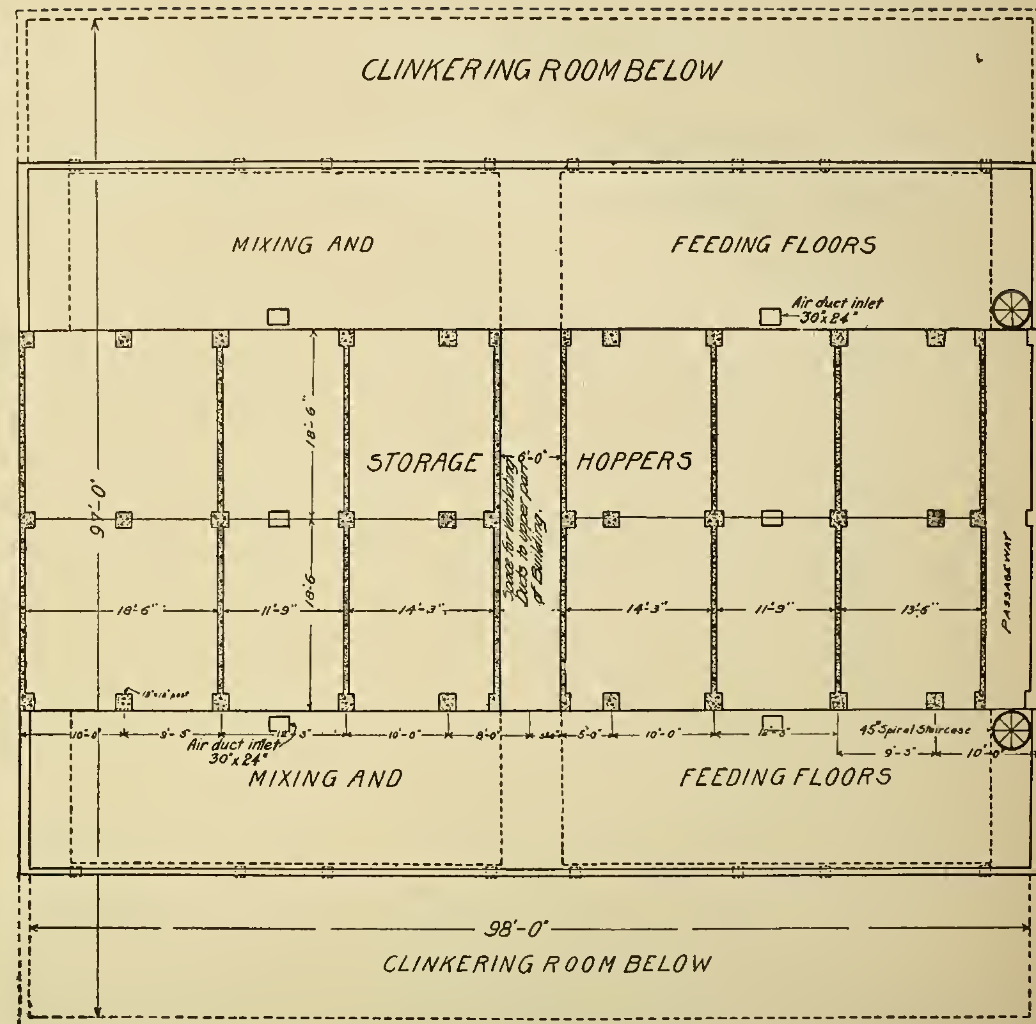
Feeding to swine is a method of disposal applicable to garbage only. It is used in Worcester, Mass., where about 3 000 pigs are kept to dispose of the garbage from a population of 130 000 people. The cost of disposal is about 85 cents per ton of garbage after deducting receipts from the sale of pigs.

The reduction process of disposal is also applicable to garbage only. It consists, briefly, in causing the garbage to be separated into three parts: water, grease and a dry material called tankage, which is useful as a base for commercial fertilizers.



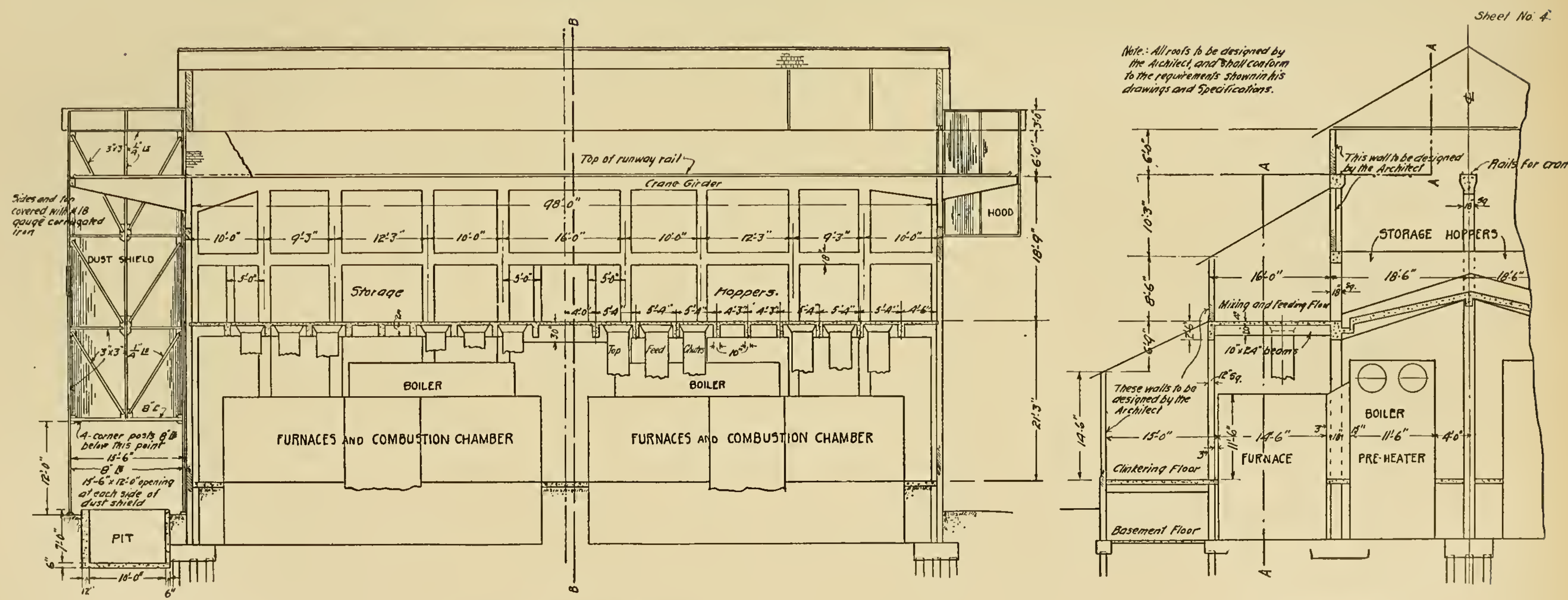
PLAN AT ELEVATION OF CLINKERING ROOM

FIG I.



PLAN AT ELEVATION OF MIXING AND FEEDING FLOORS

FIG. 2.



SECTIONAL ELEVATION ON A-A

CROSS SECTION ON B-B

Fig. 3.

Incineration or burning of the mixed refuse of the city is the method of disposal recommended by Mr. Hering, and a refuse incineration plant is now under construction. There are two classes of plants designed to burn refuse. One of these is the natural outgrowth of the early American garbage crematory, which is designed to burn garbage only, and which requires the use of coal, oil or other auxiliary fuel. A plant of this kind is now in operation on Jones Island and burns the garbage of the city. Coal is the fuel used.

The other class of incinerator is based largely on experience abroad and is designed to burn mixed refuse. As distinguished from the refuse incinerator, the garbage crematory commonly burns garbage only, requires the use of an auxiliary fuel, operates at comparatively low temperatures and is not used to generate steam. Refuse incinerators, on the other hand, burn mixed refuse, use no additional fuel, operate at temperatures averaging 1500 degrees fahr. and generate useful steam.

These high-temperature refuse incinerators can be classified according to the method of charging. There are the bottom-charged incinerators, which are always charged by hand, and the top-charged incinerators, which may be charged by hand or mechanically. The bottom-charged incinerator is a front-fed or a back-fed incinerator depending upon whether the refuse is shoveled in through openings in the front wall or back wall of the furnace.

The Milwaukee Refuse Incineration Plant is a top-charged plant. It is also a mechanically-charged plant, because the refuse will be charged on to the grate through a mechanically operated dcvice.

The Milwaukee Incinerator.

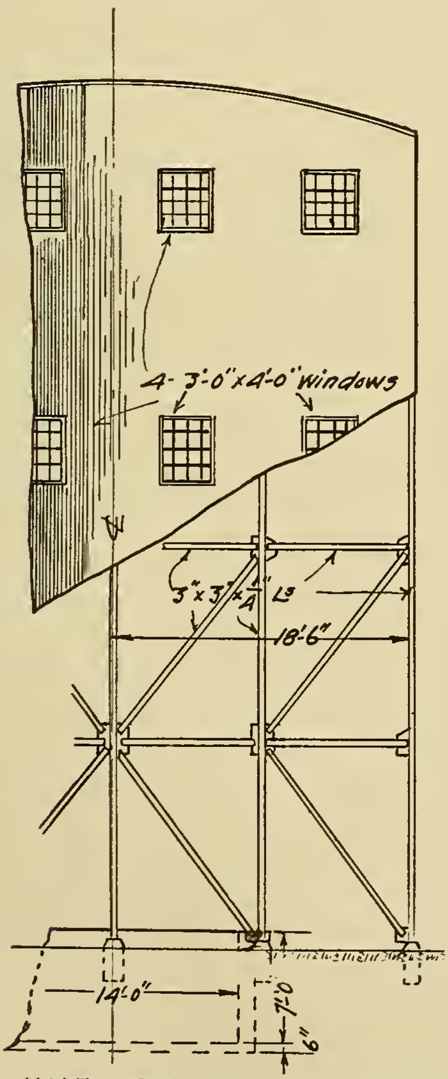
Figures 1, 2 and 3 show, in plan and sections, the plant designed for Milwaukee to burn the gradcs of refuse which have been described.

The building is about 100 ft. square and 45 ft. high to the eaves at the highest point, and the chimney is located west of the building, about 20 ft. from the wall. The plant comprises: (1) the two cranes and crane runways; (2) the storage hoppers; (3) the mixing and feeding floors with the mechanically controlled tubes for charging; (4) the floor for fans and fan engines; (5) the two clinkering floors on which the furnaces will front and between which will be the boilers, generators, office room and lavatory; (6) the basement, in which the clinker cars will operate and

which will make the settings of the furnaces and boilers accessible; (7) the main flue running east from the center line of the building; (8) the radial brick chimney; and (9) the recording and measuring instruments.

The foundations above the piles, the columns, floors, storage hoppers and crane runways will be built of reinforced concrete. The walls of the building will be of brick, and the roof of red reinforced cement tile.

The crane runways will extend out of the building over the roadways at the north and south ends of the plant. At the north end of the plant the garbage carts with their removable boxes will arrive. Bottom dumping rubbish, ash and manure wagons will deposit their contents into boxes placed in a special dumping pit at the south end of the building. The cranes, as theytravel outside of the building, will be protected by galvanized iron hoods.



HALF ELEVATION OF DUST SHIELD

Fig. 4.

Three-ton, three-motor traveling cranes will be installed. They will lift the boxes from the garbage carts or from the dumping pits and will deliver their contents into the hoppcrs.

The storage hoppers will be built in four sections, one for each furnace, and each section will be divided into three compartments. Each section of three compartments will be about 36 ft. long over all and 17 ft. wide, with an average height of 7 ft. The floors of all the compartments have a slope of about 1 in 4 from a ridge along the center line of the building to the feeding and mixing floors at the foot of the slopes. At the bottom of each compartment will be a gutter covered by a perforated cast-iron plate and connected to the sewer. The hoppers are designed so that the ingredients of the refuse can be separately stored. In this way the free water in the garbage can drain away to the sewer.

Extending horizontally from the two hoppers, and separated by them, are the two mixing and feeding floors. The mechanically controlled charging tubes open at the level of these floors, there being six tubes for each furnace. The various ingredients of the refuse will be pulled down out of the hoppers and mixed properly on these floors, after which the mixed refuse will be pushed into the charging tubes.

The charging tubes will connect the feeding and mixing floors with the grates of the furnaces. They will enter the furnace through the top and will discharge on to a drying hearth at the back of the grate. In each tube, just above the furnace top, will be a door actuated by a wheel within the reach of the firemen on the clinkering floor. Turning this wheel lifts the door of the charging tube out of its sand-sealed seat and allows the contents of the tube to fall on to the hearth below. The tubes will be made of sheet steel and will be larger at the bottom than at the top. The doors will be made of plates and angles and will move on ratchet gears with an eccentric attachment to lift the door.

There are four furnace units, each of which consists of six grates or cells, a combustion chamber, an air heater and a water tube boiler. The six cells with the ducts at the back and with the combustion chamber will occupy a space 42 ft. 0 in. long by 14 ft. 6 in. wide and will be about 2 ft. high. The six cells are divided into two groups of three cells each by the common combustion chamber at the center. Each grate will have an area of about 20 sq. ft. At the back of each grate will be a drying hearth of brick. Back of this are two ducts — the hot-gas duct above and the hot-air duct below.

The hot-air duct will convey air, heated to a temperature of 300 degrees fahr., and under a pressure of about 4 in. of water, to the ash pits below the grates. This will be the air which supplies the oxygen for combustion. Fans driven by steam-engines will drive this air through an air heater placed in the second pass of each boiler below the tubes, and then through the hot-air duct and ash pit to the fuel on the grate.

The hot-gas duct will be directly over the hot-air duct and will convey gases from the combustion chamber along the duct, and through holes in the division wall between the duct and the drying hearth of each grate. These gases will be at a temperature of over 1000 degrees fahr. and will be driven by steam jets placed near the combustion chamber. These gases will absorb moisture from the fresh refuse standing on the drying hearth before it is raked on to the grates.

The furnaces will be built of brick masonry walls 18 in. to 24 in. thick, 9 in. of which will be fire brick. Special blocks will be used for the arches over the grates. The combustion chamber will extend down to the basement floor, 8 ft. below the ash pit.

The boilers will be of the horizontal water tube type, set high, with a tubular air heater set below the tubes in the second pass of each boiler. Each of the four boilers will have a rated capacity of 200 boiler h.p. The gases of combustion will pass from each group of three cells to the central combustion chamber, thence into the boilers and air heaters and, finally, through the flue into the chimney.

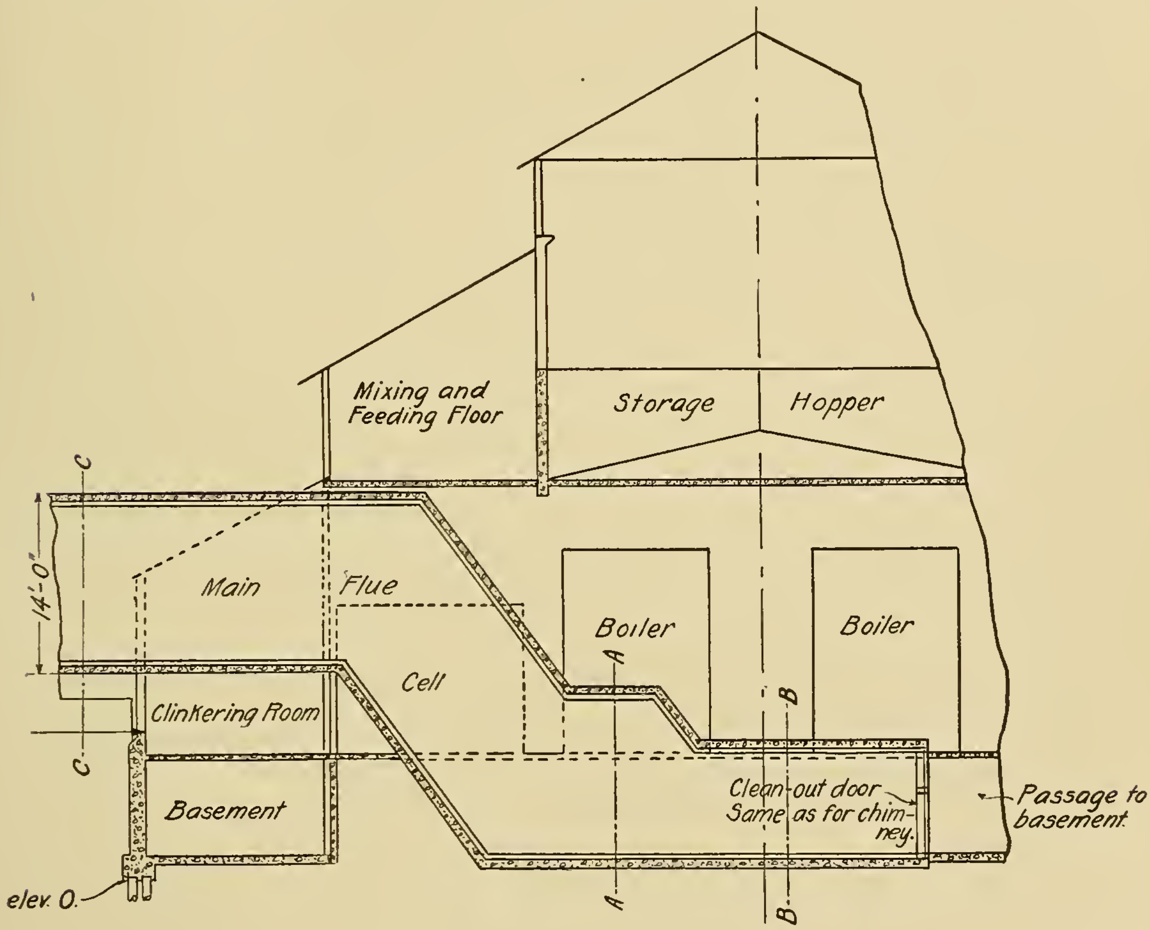


FIG. 5.

The fans and fan engines will stand on a floor raised about 5 ft. above the clinkering floor and located at the center of the building. There will be a fan and fan engine for each unit. Forty-eight inch Sirocco fans direct connected to 5-in. A, B, C vertical engines will be installed.

Clinkering will be done by firemen on the clinkering floor. As they draw the clinker from the grate, it will fall through a trap door directly in front of each grate and into a clinker car standing on rails below in the basement. This quickly removes

the dust and heat of the clinker from the firing room. Laborers in the basement will remove the clinker cars when necessary.

The basement extends under the whole building. All the boiler settings, the combustion chambers and the flue rest on foundations at the basement level and are provided with clean-out doors. In this way dust and soot can be readily removed.

The machinery is located at the level of the clinkering floor, between the furnaces and at the south end of the building. In the machinery room will be two 50 kw. 220-volt direct-current generating sets, two boiler feed pumps and a feed water heater. At the north end of the building will be the office room and a locker room for the workmen.

Instruments for measuring the temperatures and for analyzing the waste gases will be provided.

This design provides several special features to which I wish to call your attention as follows:

(1) The garbage, being stored by itself away from the ashes and rubbish, can be drained of its free water. According to analyses made by Prof. R. E. W. Sommer with Milwaukee garbage, this free water, which will drain away under pressure of the garbage itself, amounts to as much as 7 per cent. to 9 per cent. of the weight of the wet garbage. Draining this water away to the sewer reduces the amount of heat used unproductively to evaporate the moisture in the refuse, and the rate of evaporation in the boilers will be correspondingly increased.

(2) The drying hearth at the back of each grate, where the refuse is partially dried before it is raked on to the fire, increases the rate of combustion. The effectiveness of this drying hearth is increased by the hot-gas duct extending along the back of the hearth, which conducts the highly heated gases to the freshly charged refuse and reduces the percentage of moisture in the refuse before it is stoked on to the grate.

The drying hearth is also a valuable factor in increasing the life of the fire grate because it receives the impact of the refuse as it falls from the charging tube. Being of substantial brick construction, it is especially designed for this work.

(3) Storing the ingredients of the refuse separately in the different compartments of the hopper and providing a mixing floor as described will insure a uniformity in the grade of refuse fed to the fires. Where steam is generated, as in this plant, the value of this feature is evident. Furthermore, the grade of refuse can be somewhat adapted to the station load.

(4) The mechanical charging devices will make it unnecessary

to do any hand firing with wet, dirty refuse. This will reduce the manual handling of the refuse to as low a point as is possible without reducing the steaming results by removing all possibility of grading the refuse.

(5) Each operation in the conduct of the plant will be performed separately from every other. The cranesmen will work at top speed without interference from the men on the feeding and mixing floor. The men on the feeding and mixing floor will not be hindered by the men stoking the furnaces. Their whole work will be to keep the charging tubes full of refuse. Similarly, the firemen will work by themselves in a room which is free from objectionable refuse and hot clinker. Their whole work will be to keep the fires as hot as possible and to thoroughly burn all the refuse. Finally, the clinkermen in the basement will run the clinker cars out without interfering with the stoking above. These features should decrease the cost of operation.

(6) In burning refuse, a large amount of dust and soot is produced. If this dust settles on the boiler tubes it reduces the rate of evaporation and, if it goes up the chimney, it creates a nusiance. It is essential, therefore, to remove it. The arrangement of the grates on each side of a common combustion chamber causes the dust-laden gases to enter the combustion chamber from opposite directions. This will momentarily retard the velocity of the gases and cause the dust to settle out. The combustion chamber extends 8 ft. below the ash pit and forms a pocket for the detention of this dust. It is of large cross-sectional area, so that the velocity of the gases is somewhat reduced in this way. The boilers also are placed high, with their settings extending to the basement, and these settings, as well as the main flue, are all easily accessible for the removal of dust and soot and for repairs.

(7) Other features of special interest are the preheated air blast and the multicellular arrangement of the furnace grates. The air will be preheated to 300 degrees fahr. and will increase the temperature of combustion. The multicellular arrangement of the grates will keep the temperature uniform, with no decided low points in the temperature curve during clinkering.

Results.

The contractors for the Milwaukee work have guaranteed, under bond, to maintain an average temperature in the combustion chamber of 1500 degrees fahr., and to evaporate 1.1 lb.

of water from and at 212 degrees fahr. per pound of average annual refuse burned.

According to the analyses and calorific values of the refuse already given, these results should be obtained. That similar results have been obtained elsewhere in practice is well known. I will briefly mention one or two such instances.

In Seattle, Wash., there is a 67-ton bottom-charged refuse incinerator which has been in operation since January, 1908. Complete records of the operation of this plant have been kept and show satisfactory results. The temperature in the combustion chamber is almost always higher than 1250 degrees fahr., and the evaporation by actual measurement averages slightly more than 1 lb. of water per pound of refuse burned. The steam is used for the following purposes: (1) The operation of a 250 h.p. generator in parallel with the city lighting system; (2) the operation of a steam laundry; (3) the operation of a dry kiln in a kindling factory; and (4) the operation of a rock crusher with elevator and screens, which is used for the purpose of crushing and screening the clinker developed at the plant.

At Greenock, Scotland, there is a mechanically charged refuse incinerator which, for the twelve months ending January 31, 1909, developed an average of 67.2 kw.-hr. per ton of refuse burned. At this plant a temperature of from 1300 degrees to 2160 degrees fahr. is given as typical of a day's run. The electrical power generated netted about $8 000 for the year, and the clinker brought about $300. Several other plants which have been in successful operation for several years here and abroad might be mentioned. The indications are that the city of Milwaukee has made an excellent investment and, after many previous efforts, has now started out on the road which will satisfactorily solve the problem of the disposal of the city's refuse.

[NOTE. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by February 1, 1910, for publication in a subsequent number of the JOURNAL.]

CEMENT AND SAND FOR CONCRETE.

[An informal discussion before the Boston Society of Civil Engineers, May 12, 1909.]

MR. HERBERT L. SHERMAN.* — Testing cement is a rather broad subject to take up, but there are a few points that come up that are of interest to those of us who are doing a good deal of that work, and they may be interesting to you. We run across a great many difficulties in our line. A great deal of cement is tested, as you know, on the job. I do not wish, by any means, to decry the laboratory on the job; in fact, I think it is an admirable thing if properly conducted. But often, perhaps generally, this laboratory is not properly conducted. We find men testing cement on the job who leave the drafting table for a few minutes to make a few briquettes and then go back to the drafting table. Their business is not that of testing cement. Their business is drafting. It is simply a dirty job that they have got to do. That is the way they look at it, and it is unfortunate for all concerned that such men should test cement.

Another thing with which we have a good deal of difficulty is the matter of specifications. Specifications are submitted to us by engineers and architects which are only so-called specifications. Perhaps this is generally the fault of the architects rather than the engineers. I have a copy of specifications here which were recently submitted to me, and which I will read:

"All cement shall be tested under conditions and recommendations of the American Society for Testing Materials. Briquettes will be broken by a Fairbanks briquette testing machine. Cement shall not develop initial set in less than 30 min. and hard set in less than 8 hr. The average strength shall be at least 10 per cent. higher than the minimum. Minimum acceptable strength for briquettes 1 in. by 1 in. section follows:

"One day, 200 lb. Seven days, 550 lb. Twenty-eight days, 650 lb. The cement shall show no diminution in strength at any time. Fineness tests shall show at least 93 per cent. through 100 mesh sieve and 75 per cent. through 200 mesh."

Now, just note some of these recommendations. It says all cement shall be tested under conditions of the American Society

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for Testing Materials, and then goes on to say that cement shall not develop hard set in less than eight hours. The specifications of the American Society for Testing Materials are 10 hr. It says, further, that the average strength shall be at least 10 per cent. higher than the minimum. That is putting a premuim upon not making briquettes uniform. If I could make briquettes run all the same, — for example, if I could get three briquettes breaking at 600 lb. at seven days, — I should think that was wonderful work. But as a matter of fact, one may break at 570 lb. and another one at 620 lb. So this specification, calling for 10 per cent. higher than the minimum, is wrong in my estimation. Then, all they recommend is neat briquettes; it does not say neat briquettes here, but, of course, that is what it means. There is no sand test specified. Now the sand tests, as every engineer knows, are most important. And this seems a rather poor specification in that particular. Then it says the fineness tests shall show at least 93 per cent. through 100 mesh sieve. The standard test is 92 per cent. This starts out by specifying that the cement shall be tested under conditions and recommendations of the American Society for Testing Materials, and then changes them in almost every particular.

There is one thing, however, which I think is a good thing. They have specified the tensile strength tests at a certain definite figure. Now, the committee on drawing of specifications of the American Society for Testing Materials recommended, for example, that the tensile strength at 24 hr. neat should be a minimum of 150 to 200 lb. These specifications call for 200 lb. at 24 hr. It was the intention of the committee, in my opinion, that engineers should specify the strength that they wished to have. But it must be somewhere within those limits of 150 and 200 lb. In that, I think, these specifications are good, and in that only. And you can imagine how discouraging it is to those of us who are testing cement a good deal to get specifications like this and then attempt to pass on a sample of cement on its merits.

As I said before, the laboratory on the job is an admirable thing if properly conducted. But in my estimation it is not a good thing to have cement testing done by draftsmen. Another difficulty we run into is the temperature. Now, temperature is a very important consideration. The temperature of the laboratory must be kept as constant as possible, because there are very few things that will cause such variation in tensile strength, time of setting or any of the tests. I speak from

experience on this. A good many laboratories on the job are kept warm during the day, but, if it is winter, the heat is turned off at night, the storage tank freezes up and thaws out again in the morning, and the tests are of no value whatsoever, except possibly as showing the effect of alternate freezing and thawing.

Another test usually neglected on the job, and, in fact, in a good many testing laboratories, is that of normal consistency. I think one inexperienced in this line does not quite realize the value of that test. The standard specifications call for a test with the Vicat needle for determining this quality, and that is a very good thing, of course. But I have found in my experience a very simple test, and, perhaps, the old original test, is to make a ball of cement and drop this from the height of a foot on to your mixing board, and if it doesn't materially flatten out or crack the consistency is right. The Vicat needle test is perhaps better, but there is very little difference in result, and the ball test is better for the reason that it does not require so much cement and it is much quicker. The fact that it does not require so much cement is important, as we find, because we very often have samples sent us in small paper bags, with the request that we make all tests. Of course there may be enough there to make a pat and two or three briquettes, and we are expected to give a complete report on that. Of course, such a thing is impossible. But if we make our normal consistency test in that way and happen to strike it right, we can use the ball that we used in the normal consistency test for a pat and so save that much. But if any of you are sending in cement to a testing laboratory, do not send too little. Send five or six pounds. Do not be afraid of sending too much. The effect of that normal consistency test is quite important. I know of a laboratory quite near here where the method is to use 20 per cent. of water with all neat tests. Now that is a rather queer rule. Most cements when mixed in 20 per cent. water are extremely dry, and in this laboratory the briquettes are hammered into the molds with a mallet. Is it strange that they should get a tensile strength of 800 lb. neat in seven days and practically no increase in twenty-eight days? And still this remarkable strength in seven days is sometimes held up as a fine thing.

Another thing I wish to speak of particularly is the effect of alumina on cement. Some time ago the Aberthaw Construction Company approached me and asked me if I would be willing to make tests with them on the piers they wished to build at the Charlestown Navy Yard, to determine the effect of sea water.

This has always been a pet subject of mine, and I was anxious to use cements containing different percentages of alumina. So we used, among others, a cement containing a low percentage of alumina, a cement containing a high percentage, a cement which we considered a normal American Portland cement, a cement with no oxide of iron and a cement with no alumina. Professor Le Chatelier a good many years ago established the fact by laboratory tests that alumina of a high percentage was dangerous for this reason, that the sulphate in the waters acts on the aluminate of lime to form sulpho-aluminate of lime, which is an expansive. The percentage of alumina which is dangerous he did not establish, so at present we do not know. But we do know this, that the lower the percentage of alumina the better, provided we can still maintain all of the properties of true Portland cement. All of the tests to date we have made on the cement for the navy yard piers have been normal, except in the case of iron ore cement. This is made in Germany, and is now, I understand, made commercially. The alumina is entirely replaced by oxide of iron. According to the laboratory tests, this should prove ideal for work in salt water, the sulphates in the sea water not having any alumina, of course, to act upon. I have made some tests on this iron ore cement and here are my results:

	Per Cent.
Loss of ignition	0.91
Silica	24.28
Alumina	0.94
Oxide of iron	9.08
Lime	62.12
Magnesia	0.43
Sulphuric anhydride	1.75

Note that the oxide of iron, 9 per cent., replaces all of the alumina practically. Then the physical tests on that give:

Initial set	45 min.
Final set	26 hr.
Fineness, No. 100 sieve	95.8 per cent.
Fineness, No. 200 sieve	82.6 per cent.
Accelerated tests, boiling and steam	Satisfactory.
Specific gravity	3.267.
Tensile strength, 24 hr. neat	Not hard set.
Tensile strength, 48 hr. neat	223 lb. per sq. in.
Tensile strength, 7 days neat	441 lb. per sq. in.
Tensile strength, 28 days neat	641 lb. per sq. in.
Tensile strength, 3 months neat	796 lb. per sq. in.
Tensile strength, 7 days, 1–3	132 lb. per sq. in.
Tensile strength, 28 days, 1–3	234 lb. per sq. in.
Tensile strength, 3 months, 1–3	327 lb. per sq. in.

That is as far as we have conducted the tests at present. Note the time of setting. The aluminates in cement are responsible mainly for the setting properties, and that is shown here very well with that extremely long setting time. Of course it is impossible at the present time, or almost impossible, to use that cement commercially. That setting time is too long for many of us to wait. We cannot wait over twenty-four hours for the concrete to set. And so I think that, perhaps, commercially, this will never prove a success with such a small amount of alumina. I think that a cement could be made which might contain, say, 2 per cent. of alumina, or possibly 3 per cent., which would give enough alumina to cause it to set properly and then would still have the effect of being proof against the action of the sulphates in the sea water by reason of the small amount of alumina. Of course, this is entirely supposition on my part, but I do not think really that that amount of alumina would be dangerous. I think that is all I have to say.

Impurities in Sand for Concrete.*

Mr. Sanford E. Thompson. — During the last two or three years attention has been called to several cases where concrete failed to harden which could not be traced to the quality of the cement. Some of these failures have been quite thoroughly investigated. One in particular was investigated to a point where quite definite conclusions were reached, and will serve as an illustration of at least one of the causes of poor concrete.

It has been proved conclusively that the sizes and the gradations of sizes of particles of sand affect the density, strength and permeability of the mortar, and definite laws governing these relations have been framed, notably by Mr. Feret† in France, which show that with sand having grains of known sizes the strength of the mortar may be estimated. These laws have been corroborated in a general way by tests in the United States and elsewhere.

In this country also further tests have shown the effect of scientific methods of proportioning or grading the aggregates of the concrete upon its density and strength.‡

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* This discussion was also presented to the American Society of Civil Engineers at its annual convention, July 8, 1909, and the original imprint appears under this title in the Proceedings of that society for September, 1909, page 973.

† *Annales des Ponts et Chaussées*, IV, 1892.

‡ See "Laws of Proportioning Concrete," by William B. Fuller and Sanford E. Thompson, Trans. Am. Soc. C. E., Vol. LIX, p. 67.

However, every little while one runs across a sand which absolutely fails to obey the laws of gradation of sizes or of density. Not only may the mortar or concrete made from such sand fail to show the strength which would be expected, but it actually fails to harden, or hardening which should take place inside of a week is delayed for perhaps two or three months.

Frequently the sand which produces such bad results looks all right, and those who have had much experience in concrete construction are deceived by the appearance. The mechanical analysis of the sand, that is, the gradation of sizes, may be good, and it may appear clean, and yet the quality may be such that it has to be absolutely prohibited from use in concrete, while if used without previous testing it will cause failure.

This does not disprove the laws referred to. It simply indicates that there is something further, that the laws of density apply to a clean sand, and that frequently there is some other material in the sand which affects the combination of the sand and cement either mechanically or chemically, or perhaps both. Such results, such failures of the mortar and concrete to set, show the absolute necessity, not merely of a careful examination of a sand which is to be used, not merely of a mechanical analysis to determine the sizes of the particles, but of a laboratory test, as thorough a test, in fact, as would be given to the cement itself.

In the special case referred to, a two-story machine shop with concrete walls was being erected by a local contractor with no engineering advice except in the preparation of outline plans. The walls of the basement were 12 in. thick, of the first story 10 in. thick, and of the second story, 8 in. The interior of the building was mill construction with timber beams and plank floors. One night when the walls were just above the level of the second floor, during a severe wind storm, the building collapsed. An examination by the speaker, who was called upon to make an investigation immediately after the accident, showed that the concrete, although mixed in proportions 1 : $2\frac{1}{2}$: 5, had failed to harden even in the basement.

The concrete of the entire building was so soft that although parts of it had been laid for at least two months, a knife blade could be thrust into it, and it was even difficult to pick from the wall a piece of concrete hard enough to carry away as a sample.

The appearance of the concrete was dark and dirty. There was a thin, hard skin on the outside which had helped to deceive the contractors into believing that the material would eventually harden, although they were by no means satisfied with it.

Investigation showed that the concrete had been proportioned 1 : $2\frac{1}{2}$: 5 and mixed in a satisfactory manner. It was hand mixed, but apparently well done, and tests of the actual proportions by analysis of the concrete were considered unnecessary.

It was evident that the cause of the trouble lay in the materials. The last of the carload of cement had been used, only the empty bags remaining, and because representative samples of this cement could not be obtained, it was necessary to test the rest of the materials much more carefully than otherwise would have been necessary.

The sand and gravel were taken from the site of the building when excavating the cellar. The gravel was ordinary New England gravel, ranging from fine, that is, $\frac{1}{4}$ in. particles, up to perhaps 2 in. in diameter. It was fairly clean. Some of the pieces were slightly coated with dirt, but no more so than is almost always found in a gravel bank.

The gravel screened contained about 12 per cent. of sand finer than $\frac{1}{4}$ in. size; that is, the screening was imperfect. However, this is almost always the case with screened gravel, so that in gravel concrete there is apt to be an excess of sand over the nominal proportions specified. In screening, a part of the sand, especially on wet days, is carried down with the larger stones.

The gravel was washed, as gravel is usually washed in hand-mixed concrete. A hose was turned on to the pile before the mixing was begun, and the fine material was washed down to the bottom of the pile and shoveled into a wheelbarrow with the rest. Then the gravel from the barrow was dumped on to the mixing platform, and again it was washed with the hose, the dirt simply flowing with the water from the surface to the bottom of the pile to be shoveled up and mixed with the gravel in the concrete. This is the ordinary but ineffective way of washing gravel in hand mixing, unless special apparatus for washing is employed.

The sand appeared good. In some places it was rather dark colored, but most of it would pass an ordinary inspection and would be called a sand of fairly good quality, certainly good enough for the work which was being done. The results of the mechanical analysis of the sand, which are given in an appendix, were above the average. Three per cent. by weight passed a No. 100 sieve, and about 25 per cent. was caught on a No. 8 sieve, but a closer examination of the bank showed considerable

variation in the sand; in some places it was rather dark and reddish in color, while piles where it had dried out looked "dead."

A practical test was suggested by the representative of the cement company, which had never before come to the attention of the speaker. Taking a double handful of moist sand from the pile, he allowed the sand to run through between his hands as they were held with the thumbs up about 1 in. apart, at the same time moving his hands back and forth. Repeating this operation several times, always taking naturally moist sand from the interior of the bank between the fingers of both hands, there was collected a dark slimy substance which contained scarcely any grit. Some of this scraped from the fingers and afterwards tested by ignition was found to consist almost entirely of vegetable matter.

A further examination of the bank showed that in places where it had been cut to a vertical face for an excavation or for screening out the sand, the rain had washed down from the surface soil a material similar to that which had collected between the fingers on the above test, which formed a scum on the vertical face of the bank.

The surface soil was ordinary medium quality of loam with, however, one or two dark, almost black, streaks in it, about half to three quarters of an inch thick.

All the indications seemed to point to the cause of the trouble being vegetable matter in the sand, and vegetable matter which had apparently been washed down by the rains from the surface soil into the porous sand and gravel underneath, gradually coating the grains.

Tests of Sand. — Samples were taken of the sand and stone and subjected to thorough tests. The mechanical analysis has been referred to and is shown in full in Table 1.

Very fortunately for purposes of comparison, the speaker happened to have in his laboratory a large sample of another sand which had been used satisfactorily in the construction of a reservoir * near Boston, which, because of its size and shape, 100 ft. in diameter and nearly 50 ft. high, required special tests of its materials. The mechanical analysis of this good reservoir sand (shown in Table 1) was found to be almost identical with the sand used in the building which failed; moreover, the chemical composition was also practically identical, each containing about 75 per cent. quartz.

* See *Engineering Record*, January 12, 1907, p. 32.

TABLE 1. — MECHANICAL ANALYSIS.

Analysis No.		A-92.			A-96.		
Description		Average Sand from Excavation.			Reservoir Sand.		
Date of collection		May 5, 1908.			1907.		
,, ,, analysis		May 8, 1908.			May 9, 1908.		
Percentage of Moisture		2.6 before drying.			0		
Size of Sieve.		Total Weight Passing.	Total Percentage Passing.	Percentage Passing ¼-in. Sieve.	Total Weight Passing.	Total Percentage Passing.	Percentage Passing ¼-in. Sieve.
Inches.	No.						
1.50	1½ in.	97.0	100.0	100.0	100.0	100.0	100.0
1.00	1 in.	97.0	100.0	100.0	100.0	100.0	100.0
0.50	½ in.	97.0	100.0	100.0	100.0	100.0	100.0
0.25	¼ in.	92.7	95.6	100.0	96.2	96.2	100.0
0.16	5 in.	81.8	84.4	88.4	88.9	88.9	92.5
0.0583	12 in.	56.5	58.2	61.0	68.2	68.2	71.0
0.0335	20 in.	39.5	40.7	42.6	48.2	48.2	50.1
0.0148	40 in.	14.6	15.0	15.8	17.0	17.0	17.7
0.0055	100 in.	2.6	2.7	2.8	2.3	2.3	2.4
0.0030	200 in.	1.8	1.9	2.0	1.1	1.1	1.1

Notwithstanding this apparent similarity, 1 : 3 mortar from the reservoir sand gave a strength of 272 lb. in 7 days and 332 lb. in 28 days, while the poorest sample of the sand in question gave an average of 20 lb. in 7 days and 75 lb. in 28 days.

Volumetric Test. — To be sure that the bad quality of the sand was not due to the shape of the grains, which might prevent proper compacting and consequently an excess of voids in the mortar, volumetric tests were made and the density was found to be normal. The density of 1 : 3 mortar made with the sand in question was 0.679, and that of mortar made from the reservoir sand in the same proportion was 0.683.

Mica. — A little mica was observable in the samples. A careful examination, however, indicated that this was not sufficient to cause trouble.

Clay. — It has been sometimes claimed that clay matter is injurious to sand from a chemical standpoint. An examination of the chemical analysis shows, however, that the amount of clay, although large, was approximately the same as in the good reservoir sand, and, therefore, cannot be considered as the cause of the poor quality.

Tensile Tests. — The tensile strength of the mortar from the sand in question, as already stated, averaged 20 lb. per sq. in. in 7 days and 75 lb. in 28 days.

The tests in different series using sand from different parts

of the bank ranged in the 7-day test from 11 to 40 lb. To be sure that the cement used in testing or that the laboratory methods were not at fault, tests were made in two different laboratories and with three different cements. Three different proportions were also used, namely 1 : 2½, 1 : 3 and 1 : 3½. Specimens were stored for comparative tests in air, in moist closet and in water. The results all checked so closely as to eliminate the question of cement or of manipulation.

Comparison of Moist and Dry Sand. — A comparison of 1 : 3 mortar made with the moist sand as it came from the natural bank and from the same sand after drying showed some relative increase in strength due to the drying. In this series the average strength at 7 days of the sand direct from the bank was 8 lb., and of the dried sand mortar, 23 lb.

Comparison of Natural Sand and the Same Sand after Washing. — A comparison of the sand in question before and after washing is as follows:

Unwashed sand, 40 lb. at 7 days; 102 lb. at 28 days.
Washed sand, 97 lb. at 7 days; 196 lb. at 28 days.
Standard sand, 200 lb. at 7 days; 275 lb. at 28 days.

The grains of the washed sand were not thoroughly clean.

Microscopical Examination. — The microscopical examination of the grains of sand as obtained from the bank showed them to be covered with a dark brown coating which did not readily brush or wash off. The particles of the Waltham sand, on the other hand, were clean. A strong magnifying glass was found efficient in examining the grains for coating.

Washing Tests. — To examine and test the character of the silt in the sand it was found necessary to remove the fine matter by washing.

To compare the results by washing and by screening out the silt through a No. 100 sieve, tests were made in both ways with the following results:

Worst sample of defective sand: 1.60 per cent. silt by washing; 1.14 per cent. by screening.

Average sample of defective sand: 2.46 per cent. silt by washing; 2.68 per cent. silt by screening.

Good Reservoir sand: 1.16 per cent. silt by washing; 3.66 per cent. by screening.

Although there is but slight difference between the results from washing and from screening, the chemical analyses indicate that the washing removes much more of the deleterious vegetable

matter than the screening, so that this process should be followed when testing silt in sand.

It is noticeable in the above results that the poor sand gave a larger per cent. of silt by washing than by screening, while the good sand gave a much smaller per cent. by washing, indicating that in the latter case a large proportion of the very fine material was of heavier mineral origin.

The method used in washing to remove the silt was a very simple one, but was found more effective than several other more elaborate methods that were tried. The sand was placed in a large-mouthed quart bottle about half full of water and shaken thoroughly. The dirty water was poured off and the operation repeated several times until the water was nearly clear. The wash water was then evaporated, the residue thoroughly dried, and the loss on ignition, which determined the quantity of organic matter, was found.

Before igniting, the silt was passed through a No. 100 sieve to remove large particles of dirt which evidently would not be injurious if distributed through the mortar.

Chemical Analysis of Silt. — Both the poor sand in question and the good reservoir sand were washed and a chemical analysis made of the silt, including a test of the residue by ignition. The analyses of the silt were as shown in Table 2:

TABLE 2.
ANALYSES OF SILT.

	Reservoir Sand. Per Cent.	Average Sand B from Silt. Per Cent.	Worst Sand G from Silt. Per Cent.
Moisture	7.80	8.24	13.07
Silica	54.12	45.32	34.94
Alumina	23.10	25.13	20.80
Oxide of iron	9.00	6.71	5.90
Lime	2.07	1.93	
Organic matter	2.50	11.86	26.33
Approximate percentage of clay	45	50	35

Inspection of these analyses shows but one notable difference: The organic matter in the silt from the reservoir sand was 2.50 per cent., while in the silt from the poor sand it was very high. In one of the samples of poor sand the organic matter was 11.9 per cent., and in the other, 26.3 per cent. When ignited, the organic matter in the poor sands gave off a peculiar odor of woody fiber, or leaf mold, thus indicating its probable vegetable origin. The good reservoir sand, on the other hand, gave no

appreciable odor and showed a reasonably small percentage of organic matter.

Reference is made above to the comparison of screening and washing. Tests by ignition show that frequently double the percentage of organic matter is obtained by washing that is obtained by simply screening.

It is noticeable that the silica is low, but in this connection it must be remembered that this is the analysis of the silt and not of the total sand.

Introducing Silt into Standard Mortar. — To still further confirm the conclusion that the silt was the cause of the trouble, a mortar was made up of 1 : 3 standard sand with an addition of $1\frac{1}{2}$ per cent. of silt based on the weight of the sand. The resulting tensile strength of the mortar was 29 lb. per sq. in. in 7 days and 107 lb. in 28 days, whereas the normal strength of the standard sand mortar was about 200 lb. in 7 days and 275 lb. in 28 days.

A similar test was made by introducing 1.5 per cent. of silt into neat cement and the resulting strength was about one half that of the neat cement without silt.

Concrete Tests.— Specimens of concrete were also made, using sand from different parts of the bank in different tests. The cement used in these tests was of a well-known brand, which was carefully tested to see if it was normal. The poor sand and gravel from the site of the building were used in the test as well as the good reservoir sand and gravel. The blocks were broken at the age of about 18 days at the Watertown arsenal, with the results shown in Table 3.

TABLE 3.

COMPRESSIVE STRENGTH OF CONCRETE IN POUNDS PER SQUARE INCH.
AGE, 18 DAYS. PROPORTIONS, 1 : $2\frac{1}{2}$: 5.

Aggregate.	Cement H. Individual.	Cement H. Average.	Cement A. Individual.	Cement A. Average.
Sand A and Gravel E,			200	200*
Sand $\frac{1}{4}$A + $\frac{3}{4}$B and Gravel E,	818		625	
	692	755	749	687
Sand W and Gravel E,			653+	
Sand W and Gravel W,			1 505	1 505†

NOTE. — Sand A. Worst sand from site of building.
Sand B. Average sand from site of building.
Sand W. Good reservoir sand.
Gravel E. Screened gravel from site of building.
Gravel W. Screened reservoir gravel.
* Only one specimen, but a good specimen.
† Only one specimen, and possibly slightly defective.

Hardening of Specimens. — Careful watch was kept of the specimens of concrete and of mortar as they hardened, and pats of the concrete were also made. The mortar and concrete made with the good reservoir sand set up hard within 24 hr. with a light gray color, while the other specimens remained so soft that they could not bear the pressure of the thumb nail for several days.

Conclusions. — As already stated, the tests indicated conclusively that the trouble with the sand was due to the vegetable matter which it contained. Subsequent tests of other sand and examination of structures indicate this to be a common cause for poor mortar or concrete. In many cases no failure results, but the concrete does not harden properly and never becomes as strong as it should.

The percentage of silt given in the chemical analysis of the silt appears large, in one sample being 11.9 per cent. and in another 26.3 per cent. However, when given in terms of the total sand it is a very small percentage because there is so small an amount of silt in the sand. Based on the weight of the total sand before washing, therefore, the percentage of silt as it comes from the bank is 0.27 per cent. in one case and 0.39 per cent. in another case, an extremely small amount, and one which would not show up by any test of settlement in water or rubbing in the palm of the hand.

These and other tests indicate that there are two percentages of vegetable matter which appreciably affect the quality of a sand. First, the percentage of vegetable matter in the silt, and, second, the percentage of vegetable matter in the sand. Although the tests thus far made are too few to draw definite quantitative conclusions, it would appear that, in order to be injurious, the percentage of organic matter in the silt must be more than 10 per cent. and at the same time the percentage of organic matter in the total sand must be more than $\frac{1}{10}$ of 1 per cent.

Both of these conditions are necessary because it appears from tests that in certain cases the percentage of vegetable matter in the silt may be above 10 per cent., but there may be so little silt in the sand that the percentage of organic matter in the total sand will be less than $\frac{1}{10}$ of 1 per cent., and the sand will pass the tensile test.

Whether the cause of the results is due entirely to chemical action or whether it may be due in part to mechanical action, the organic matter surrounding the grains so that the cement will

not adhere, has not been determined. Most probably the cause is chiefly chemical, but in a small measure also mechanical. The subject appears to be of sufficient importance to warrant thorough further investigations.

In conclusion, special stress should be placed upon the necessity in concrete work of thorough tests of the sand. It is not merely necessary to examine sand with the eye; it is not sufficient to test it by rubbing it in the hands; it is not enough to make a mechanical analysis and to determine the sizes and the gradations of the particles, but in every case, unless the sand is from a bank of known good quality and has been previously tested, as careful tests should be made as are required of the cement. Probably the best test is the ordinary tensile test required by the Joint Committee on Concrete and Reinforced Concrete which requires that "mortars composed of one part Portland cement and three parts fine aggregate by weight when made into briquettes should show a tensile strength of at least 70 per cent. of the strength of 1 : 3 mortar of the same consistency made with the same cement and standard Ottawa sand."

In case a sand must be used immediately, with no time to make tensile tests, or in case special investigations are needed to determine the causes of poor quality, the washing test and determination of the organic matter is of special value. The mechanical analysis, which shows the proportions of the grains of different size, is also of great value as indicating the comparative value of different sands which are free from organic matter.

Mr. J. R. Worcester. — Mr. Sherman spoke about the specifications of the Society for Testing Materials, and it seems to me that it would do no harm to emphasize a little more than he did one clause which needs further elucidation by the engineer in making his specification. In making specifications for cement, if you say it shall be in accordance with the specifications of the Society for Testing Materials, it is not quite sufficient. As you all know, the clause covering the tensile tests of briquettes has limits — 150 to 200 and so on. Those limits have almost invariably been misunderstood, in spite of the footnotes and the precautionary clause added by the committee. I was quite astonished a few days ago to be told by one of the dealers in cement here in Boston — a man who sells a great quantity — that he never had heard of any other interpretation of that specification than that cement that came within the limits was all right. I asked him how about the upper limit, — whether he would reject cement that went above the upper limit. No, he wouldn't

exactly do that. The amount of it was that he thought anything that went above the lower limit was safe. The intention of the committee was that the engineer in making his specifications should say what his minimum tensile strength should be and should specify a limit somewhere between those given. It is useless to say that the cement shall be in accordance with the specifications of the Society for Testing Materials, and then go on and give a long list of requirements which do not correspond with the specifications of the society, as did the man who wrote the specifications read by Mr. Sherman. It is necessary only to say that the cement shall correspond with the standard of the Society for Testing Materials and that the tensile strength shall be so much at various periods.*

I have a little to say along the same line followed by Mr. Thompson, and possibly I shall repeat a little of what he has said with regard to sand. But it may be well to emphasize his points. We have all, I think, experienced difficulty in determining what is good sand and what is not good sand. I know that in a great many instances I have been asked to pass an opinion upon a sample of sand, and not until comparatively recently have I had any idea how to do it. I think we all have tried washing it — that is, putting water on to it to see how much the water is discolored. But Mr. Thompson's experience has clearly proved that that is not all that is necessary. The granulometric analysis of sand has been advocated by some, but I have yet to learn of any specification for a granulometric analysis that will inevitably discriminate between a good and a bad sand. It may be helpful, but until we know more about just what compositions it is safe to pass and what not to pass, it does not settle the point very satisfactorily.

The recommendation made by the joint committee on concrete and reinforced concrete that sand to be used on the job shall be tested in mortar briquettes along with the cement, to see what tensile strength will be developed in a seven-day period and how that strength compares with the tensile strength of mortar made from standard sand, seems to me to be the most satisfactory requirement that has so far been devised. We have had occasion this past winter to pass upon many kinds of sand from different places, and we had in the specification adopted that rule of the joint committee that the sample should develop

* Since this explanation was made, the Society for Testing Materials has revised the specifications and the uncertainty referred to no longer exists.—J. R. W.

70 per cent. of what the same cement would develop with standard sand. Possibly you may be interested to know the result of the work we did along that line and how satisfactory it proved.

I might say right here that in Boston sand is one of the hardest things to obtain. We have no trouble in getting cement. We can get any quantity of that, and good cement, but sand is not so easy to obtain here in Boston; and a great deal of what is being used and what had been used in the past is mighty poor. Some of it which looks all right and which will wash all right — and I believe will pass a fair granulometric test — will make a mortar or concrete which oftentimes is condemned because it is poor concrete, and it isn't the fault of the cement either. I won't weary you with the detailed figures of the tensile results, but I will read the percentage of strength that the sand which was being tested developed of the standard sand briquettes at 7 days and 28 days, the results generally being based upon an average of six briquettes for each period. We had fifteen different kinds of sand which we tested.

The first one at 7 days developed 66 per cent. of the standard, and at 28 days, 59 per cent.

The second at 7 days developed 67 per cent. of the standard, and at 28 days, 60 per cent.

The third at 7 days, 83 per cent.; at 28 days, 92 per cent.

The fourth at 7 days, 95 per cent.; at 28 days, 109 per cent.

That was a constant improvement, as the contractor discovered that we were testing. The order is chronological. Then we had a break.

The fifth at 7 days gave 48 per cent.; at 28 days, 57 per cent.

The sixth at 7 days, 88 per cent.; not tested at 28 days.

The seventh at 7 days, 57 per cent.; at 28 days, 57 per cent.

The eighth at 7 days, 133 per cent.; at 28, 132 per cent.

The ninth at 7 days, 107 per cent.; at 28, 85 per cent.

The tenth at 7 days, 73 per cent.; not tested at later period.

The eleventh at 7 days, 107 per cent.; at 28, 89 per cent.

The twelfth at 7 days, 57 per cent.; at 28 days, 57 per cent.

The thirteenth at 7 days, 76 per cent.; at 28 days, 75 per cent.

The fourteenth at 7 days, 96 per cent.; at 28 days, 70 per cent.

The fifteenth at 7 days, 116 per cent.; not tested at later period.

To summarize these results, we found that out of 15 samples of sand tested, 5 failed to meet the requirements and were re-

jected; 5 proved better than the standard sand, and 5 fell between the limits of 73 per cent. and 92 per cent. of the standard. That is, two thirds were accepted and one third rejected. We also noticed one or two other things. Those that failed at 7 days maintained just about the same percentage of the standard at the 28-day period. I will say that the determination was made at 7 days, and the 28-day tests were made as a sort of check to see whether it was safe to work by what we could obtain at the 7-day period. None that were rejected on the 7-day test would have been accepted if they had been judged by the 28-day period, because the percentage did not go above the limit. On the other hand, none accepted on the 7-day test would have been rejected if they had been subjected to the 28-day test. These results, of course, are not conclusive, and we have got to learn by further experience; but so far as we have gone we find the method very satisfactory as a criterion for determining what the sand is good for. I would say that the process does not generally delay the work. Of course it requires the contractor to get the sand in quantity enough so that he need not use it for seven days, the same as he does his cement, and the time he is waiting for sand is only the time he is waiting for his cement tests. Moreover, it gives you something definite in your specification, and oftentimes the specification is valuable only in so far as it assists the engineer to make a positive decision. An engineer in looking after work is often handicapped by a clause that is dependent on judgment and susceptible of argument. This is a requirement that you can determine absolutely and will greatly fortify you in condemning an inferior material.

Mr. E. S. Larned. — The topics under discussion this evening are of unusual interest to me and have commanded my almost undivided attention for a number of years past.

I rejoice to see engineers more generally recognizing the necessity of carefully testing sand before use in mortar or concrete work, and hope that the importance of so doing will cease to be a subject for discussion with architects and engineers generally by reason of its universally acknowledged importance.

The American Society for Testing Materials has taken a long step in advance in proposing a specification and test requirement for sand, requiring that it show at least 75 per cent. of the strength developed by the Standard Ottawa Sand in laboratory tests. This is not a difficult requirement to meet, since a fairly good clean bank sand, moderately coarse and fairly well graded, will show results superior to the Ottawa sand, which is artifi-

cially prepared to comparatively uniform size for the purpose of securing uniform results in testing cement for purposes of comparison.

Much has been said and written about the advantages and disadvantages of clay and loam in sand, and some experimenters report better results by adding given percentages of clay and loam to sand than in testing the sand without the addition of this foreign material. Opinions based upon the results of such laboratory experiments as above noted have been the cause of wretched results and sometimes actual failures in practical operations, and I think should be avoided without exception.

Conditions may be found where a sand entirely free from clay or loam cannot be procured except at almost prohibitive cost. In such cases, careful and thorough laboratory tests should be made of the material, and the required strength of mortar fixed, if possible, by the addition of cement.

In considering the meaning of tests where clay has been added in different percentages to the sand, we must take into account both the character and size of the sand grains, the proportion used and the amount of water used; also the method of keeping the briquettes either in air or water between the time of making and the application of the test load.

While some experimenters have found that in certain sands they can use considerable additions of clay with good results, their determinations cannot be taken literally as applying to practical conditions.

It is a well-known fact that clay, fine, dead sand, even though siliceous, and other foreign materials, seriously retard the hardening of cement mortars and consequently would likewise affect concrete.

If the sand be perfectly dry, as in the case of laboratory tests, and the clay also dry and finely pulverized, you can see that a more intimate and even mixture can be obtained than in the case where the sand may be moist and the clay occurs in lumps. The results are also affected by the degree of mixing and manipulation, which in the laboratory is carried to a greater refinement then it ever reaches in practical operations.

If a moderately coarse sand be used, and the proportion of cement added is not quite sufficient to fill the voids in the sand, it is conceivable that a small addition of clay, sufficient in addition to the cement to completely fill the sand voids, would result in a denser mixture and consequently increase the compressive strength of the mortar. This result is contingent, however,

upon the sand and clay being dry when first mixed and the cement thoroughly and uniformly distributed through the fine aggregate.

Where clay is found in association with sand in a bank, it becomes a question of how the clay is contained, i. e., whether in the nature of silt uniformly distributed throughout the sand or in layers or strata of small or considerable depth. If it occurs in the latter form, it naturally follows that it will be in the form of lumps throughout the sand, and ordinary mixing is not sufficient to break this up and distribute it uniformly throughout the sand voids, and, in consequence, weak spots will be found in the mortar or concrete made from such materials.

If the sand grains and fine gravel be coated with clay, as is often the case, it will require a comparatively wet mixture and vigorous working to dissolve the clay sufficiently to enable the cement to bond with the sand and gravel surfaces, and even then results are more or less uncertain.

The presence of clay depends upon its physical condition, or its state of division, whether in such condition that the individual atoms can mingle with the mechanical mixture as a filler, or whether it is in a colloidal, or state of semi-solution (gelatinous), such that it reacts on the total mixture so as to prevent the bonding of the cement with the sand.

It may be difficult to anticipate this in actual practice without laboratory experiments to determine the physical condition of the clay. This may be done by elutriation and testing that portion of the clay which cannot be drawn down within a certain period of time by sedimentation, and which remains in suspense, thus indicating its colloidal state, which prevents the actual bonding of the cement with the aggregate, and, therefore, setting of the concrete.

I have in mind two instances of failure directly traceable to the condition last named, and upon washing the sand and gravel before use good results followed.

Mr. Leonard C. Wason. — I can almost begin by saying that so much has been said and so well said that nothing is left for me to say. But there are a few thoughts I would like to bring out or suggest to you. The first is what is to be determined as standard tensile strength for cement. Some time ago I had an experience with a specification for cement which specified the upper limits of the American Society for Testing Materials. A certain cement was submitted to those tests. The 1 : 3 sand test passed at 7 days below the maximum and above the minimum, but was not permitted to be used pend ng the 28-day

test. During this period the cement was submitted to three other laboratories, all of the very highest standing, and there both the neat and sand 7-day and the 28-day tests were conducted and the cement passed every test satisfactorily in all the laboratories. In this first laboratory referred to the neat tests were all above the specified amount, namely, the maximum of the standard specification, but the sand tests were not. The cement was not permitted to be used. Now, while it is probably allowable for the engineer to reject the cement on that small technicality, it does not seem to me to be perfectly just that he should do so. This experience has not shaken my confidence in the cement, but has discredited the laboratory. And in cases like this I think it would be well for engineers to consider a reference to a court of arbitration, say of three or five laboratories; and if they check one another and pass the cement, the cement should be accepted irrespective of any one particular laboratory which finds in some particular respect that the cement is below the standard.

With regard to sand, in the case to which Mr. Thompson referred, the sand seemed to me with the ordinary quick test to be entirely satisfactory. Rubbed between the hands, it was sharp and gritty, left very little residue or silt; thrown into a glass of water, it showed very little clouding of the water; even when the water was stirred vigorously it was not materially clouded. The appearance of the concrete was one thing which seemed to be peculiar. I don't know how to explain it. I simply state the facts and would like to have you produce the explanation. The surface which is exposed to the air was fairly hard, — not as hard as thoroughly first-class concrete, but fairly hard, and the thickness of this shell was pretty uniform. You might compare it with the cover of a book, a little bit thicker than that, possibly one fourth to three eighths of an inch. There was just as much separation of that skin from the mass of concrete as there is of the cover from the pages of the book. The material below was just as soft as could be; you could drive a carpenter's hammer into it nearly to the claw without much effort. Relatively the outer skin was hard, and what was within gradually became hard if exposed.

I had an experience five or six years ago, not as disastrous as the one referred to, but I think due to somewhat similar causes. A dealer presented a sample of sand which was beautiful in appearance. It was light gray and apparently as clean as Newburyport sand. It was uniform in the size of the grains and

had more the appearance of beach than bank sand, although it came from a high elevation where there had been a flower garden. Without stopping to test it, this was incorporated into concrete and the concrete turned out very poor indeed. We had no question of the quality of the cement, but inasmuch as we had completed work upon this, we endeavored to save it. Here the same appearance was observed as I just mentioned — the skin was hard where it was exposed to the air, and inside of this the cement was soft. We let the forms stay on two weeks. It was still just as soft and muddy as before; you could dig it out with your fingernails to a depth of an inch without difficulty. This work went partly into a wall one story high and partly into a floor supported by the wall. And on both floor and wall we removed the forms, a board at a time, here and there. This dried out and hardened, so that at the end of a week it would ring when struck with a carpenter's hammer as well as perfect concrete. But when we would take out the adjoining board we would find it soft and muddy. We continued this process and at the end of about six weeks we had the forms entirely removed. The concrete is now satisfactory. The building — a storage warehouse — has been standing six years and has given no trouble whatsoever. But that peculiar condition of hardening on the surface first and then seeming to harden through the mass and hardening by drying rather than by chemical action, as we might expect from cement, is what puzzles me.

I have seen specifications which specified the color of sand. One architect in particular always specified light gray. Now in other parts of the country, like New Jersey, for instance, you get very red sand, full of iron, and it gives excellent results. Here we get sands which are yellow and gray and other variations of color, and all give excellent results. It seems to me that color has no bearing whatsoever upon the subject. I have seen in specifications frequently the words "foreign materials"; — sand should be sharp, clean, free from foreign materials. What is to be considered foreign material? Sometimes you find mica. That is purely mineral matter; is that foreign? Suppose there is decomposed granite; there is sure to be mica in it. Mica is a bad material for sand; gives very poor results. That word "foreign," it seems to me, is not sufficiently explicit to be used in description without further elucidation.

Sand ought to be tested, certainly, on all important works; and in my own practice on all important works it is customary to test sand when it comes from any new source. Sometimes such

sand may be found away above standard sand; sometimes below. Sometimes sand varies in quality in the same pit. If you should specify an arbitrary 7-day test for sand and have the material stored, because of the bulk it would be difficult to find storage room on a good many operations, especially here in the city where storage room is exceedingly scarce. But suppose it is necessary, because sand is variable, it would be possible to sample the sand in the pit and not allow it to be shipped until reports have been made. In this way the expense of handling large volumes of sand and storing it while the seven-day test is being made could be reduced to a minimum.

When I began concrete construction the standard mixture was 1: 3: 6 for floors, walls and practically all use. And I think that with first-class materials and workmanship that mixture is perfectly satisfactory to-day. Nevertheless, the most common specification now for this class of work is 1 : 2 : 4, and I think this is usually wise as a factor of safety. It is not common to test every bit of your work, to inspect every batch, and, therefore, if you have a rich mixture you can stand for some variations and defects in your aggregates and still be sure that your results will be within the limits of weakness. But if you have a job of sufficient size and want to spend enough money for inspection all the way through, it is possible to save the cost of inspection by a leaner mixture and still get thoroughly satisfactory results.

Nothing has been said yet about thoroughness of mixing. I will mention this very briefly, as the figures I give have all been published as comparisons between hand and machine mixing. I made some tests at the Watertown Arsenal in 1897, comparing hand mixing and machine mixing. Both were a little better done than is usual in commercial practice, and the results showed 11 per cent. greater strength from machine mixing than from hand mixing. In some later tests, where commercial practice was exactly followed under very careful supervision, the difference in strength was 25.4 per cent. in favor of machine mixing. Now this shows how thoroughly mixed concrete will help to overcome the difficulties of imperfect aggregates. An aggregate might fail with hand mixing and pass satisfactorily with machine mixing.

I also want briefly to mention in this connection some test specimens made at the Institute of Technology some years ago. I made the specimens for the students to test as thesis work. There were columns 8 in. square and 16 or 17 ft. long. It was difficult to pack them carefully, and some of the specimens were

very badly honeycombed. But the interesting feature is that although quite a percentage of the cross-section of the 8-in. square column was lost by the honeycombing — in some cases 3 or 4 in. — those specimens tested so near the average of perfect specimens that you could not attribute the loss of strength entirely to the honeycombed character of their surface. I think some engineers have overdone the matter of condemning concrete which has been rough on the surface. In certain cases, I know, such work should not be passed, but in many cases I know it is condemned where it would not produce any bad results whatsoever.

Lastly, regarding the tamping of concrete. I have no actual tests of my own, but I have in mind tests made by another man to compare tamped with untamped concrete. This, of course, was not the sloppy mixture we use in reinforced concrete, but the plastic mixture which can be tamped, and the difference was 30 per cent. in favor of the tamped concrete. The very wet, sloppy mixtures we have to-day I think are somewhat weaker than mixtures a little less wet. But I think possibly this source of weakness is overcome by the richer mixture we now use.

Mr. Worcester. — I just want to say that the testing of sand in the pit as advocated by Mr. Wason appears to me to be a snare and a delusion. The fact that the pit contains all sorts of sands is the very reason why it is no use to examine it there. The men in taking it out of the pit and shipping it to the job may intend to take out the right kind, but unless you have a tester there every time a car is loaded, they are pretty sure to get the wrong kind.

The Chairman (Mr. H. F. Bryant). — I would like to ask Mr. Thompson, when he spoke of a sand pit where it appeared that vegetable matter had come down from above, whether he meant that the vegetable matter had come down before the sand pit was worked, or during the working of it?

Mr. Thompson. — The appearance of the face of the bank I spoke of was from material which came down after the cut was open. I mentioned it as a probable explanation of the way the material had worked down through the sand before the pit was opened. In other words, it had gone on faster when it had a face.

Mr. R. R. Newman. — I have in mind a case which I think will be of interest in corroboration of Mr. Thompson's statements about vegetable matter. This was in connection with the building of filters. The same sand bank was used for sand in concrete as was later used for sand filter material. It was good sand and

everything was satisfactory regarding its use on the orignal construction. After the filters were in operation for a while and we had scraped off some of the corroded sand — sand that had become dirty — and thrown it into a pile at one side, there was a little job of concreting came up and we used some of that dirty sand — the same sand dirtied by vegetable matter. It set up very slowly indeed, showing just the effect Mr. Thompson spoke of. I should say further that the dirt in the sand was purely vegetable in character — there having been no heavy storms and no roily water having passed through the filter.

Mr. Bertram Brewer. — Mr. Sherman said something about the range of temperature in which briquettes are kept and tested, and spoke of testing out in the field on the work where briquettes are sometimes allowed to freeze. I would like to ask Mr. Sherman if he can tell us anything about the difference in temperature as affecting the strength of the concrete and what range is allowable in his experience, or, rather, how much of a change of temperature it takes to make a material difference in the strength.

Mr. Sherman. — Some time ago I made some tests for the Aberthaw Construction Company in cold storage to bring out this point. We made briquettes and stored them in rooms of four different temperatures. One of these was 72 degrees, if I remenber rightly; one was 34 degrees, one was 6 degrees above, and one was 7 degrees below zero. Those temperatures are approximate. We carried on tensile strength tests, on these briquettes for, I think, a year — at any rate, for some time — and we found that briquettes stored at the two temperatures below freezing gave no strength on 1 to 28-day tests, as we expected. The briquettes stored in the normal temperature of 72 degrees gave very good strength, and those at 34 degrees also gave very good strength. It appeared from those tests, so far as we carried them, that anything above freezing gives fairly good strength. The line seems to be 32 degrees, so far as we have tested. But in connection with this it was interesting to note that on a three-months' test the briquettes that were made in the rooms at 6 above and 7 below had some strength. These were taken to the laboratory from cold storage and allowed to thaw out. They had showed up to that time absolutely no strength; in fact, the cement hadn't even set. But at three months we found the cement had set and, on thawing out, the briquettes were fairly hard and gave some 15 or 20 lb. tensile strength, if I remember rightly.

Mr. Brewer. — One hesitates to tell his experience before such a gathering of experts. But I would just like to say that my experience corroborates the statement of the last speaker. I had a little experience in my our laboratory of that sort this last winter. I am sorry that these speakers don't think young engineers ought to have laboratories of their own, but some of us are inclined to think otherwise. At any rate, we want to try. My own experience along this very line was this. A sample of cement was submitted to me by a local dealer who wanted to carry it in stock. He could get it at a low figure and wanted to know if it was all right. We tested it and found that it fell down on the 24-hr. and 7-day tests. Two or three weeks afterward I had a call from the regular tester of the company, who was very much disturbed over the results we had secured, and, as is customary in such cases, I told him he might try it with my tester and work with him and see how he did it. He did not get as good results as my man did with the same cement. He then suggested that the reason was that my testing was done at a temperature below the standard. We tried it afterward at the standard temperature and found it made no difference whatever. In this case the temperature was about 25 degrees below the standard.

Mr. Sherman. — I do not wish to go on record as saying that young engineers should not test cement. What I wish to emphasize is that cement testing is a business. It is not a thing, as I said before, for a draftsman to do in his spare moments, while his business is something else. It is a business, something that requires a great deal of thought. It is not, of course, an exact science, but it takes a great deal of careful work.

Mr. Thompson. — There was one statement made by Mr. Wason to which I wish to take exception, because I think it may give a different impression from what he intended. That is, with reference to the gradation of the sizes of the grains of sand being no indication of the quality of the sand. I agree in general in his conclusions as to the necessity of testing, but I know he will agree with me that, provided a sand does not have some of this deleterious material in it, provided it is a clean sand, the gradation of grains does affect it a great deal, for a fine sand can never give a good mortar.

The Chairman. — I wish to recite one thing that happened a year ago in my own experience. I have not been on the work since it was done, and can only say how it looks from the report of others. The engineer in charge was unable to secure any

very satisfactory sand for this particular work. At the same time he was experimenting under my advice in the use of clays to make a watertight surface with the cement. And this very miserable sand, mixed with clay, gave remarkably good results on a three-months' test. I don't know anything about the reason, but it is a fact that a sand that did not stand up well alone showed up well when mixed with clay. If anybody has any explanation to offer of that, I would like to hear it.

A MEMBER. — What percentage of clay?

THE CHAIRMAN. — Somewhere between 5 and 10 per cent. gave the best results. The clay was dried and pulverized and then mixed a good deal like cement and added to the sand.

MR. LARNED. — In my discussion of the influence of clay on sand, I believe I said that if a sand was treated with a percentage of clay carefully dried and pulverized and thoroughly mixed it might give good results. This is laboratory work. But in my experience I have never seen sand containing an appreciable amount of clay that gave satisfactory results in practical work. It is quite likely that such things occur and may give good results, but I have never seen it. On the question of mixture, Mr. Wason referred to the popular mixture of 1 : 3 : 6, and the tendency in later tests to increase the richness. It perhaps might put me under suspicion to speak very directly or emphatically in favor of a richer proportion, because, of course, it involves a greater use of cement. But if you will believe me, I am speaking entirely independent of that, and I think I can convince you.

A 1 : 3 : 6 mixture, if perfectly made and carefully handled in the work, will undoubtedly give you very good results. But the six parts of stone must be pretty carefully selected with regard to relative sizes or you will have a concrete with mortar very poorly proportioned, and the sand must be coarse and fairly well graded in size or the cement will not fill the sand voids. And if in the process of mixing and transportation to the forms the concrete is broken up into small units, you will not get the concrete as it is mixed either by a mixer or by hand. You will get portions very fat and portions very lean, and it will go into the work just that way. Some portions of the work will be well filled and dense, and other portions will be full of voids and poor in quality. The small cost of additional cement is really a very small factor. Just on the basis of present prices of cement, I have drawn up a statement showing the difference between the cost of the lean and the fat mixture.

Cost of cement per yard of work: 1 : 2 : 4 mix, present price

of cement, \$1.85; 1 : 3 : 5 mix, \$1.43; 1 : 3 : 6 mix, \$1.28 per yard of concrete.

Now, assuming that the concrete costs \$8 per yard in place, the cement in the 1 : 2 : 4 mix costs 23 per cent. of the total cost; 1 : 3 : 5 mix, 18 per cent., and 1 : 3 : 6 mix, 16 per cent. You see there is a very small difference between the 1 : 3 : 5 and the 1 : 3 : 6, and very little more in the case of the 1 : 2 : 4.

Now comes the reinforced concrete, costing \$15 per yard, and that covers wall work, or retaining wall work, or perhaps difficult forms of foundation: the 1 : 2 : 4 mix would cost 12.3 per cent. of the total cost per yard of concrete; the 1 : 3 : 5 would cost 9.5 per cent., and the 1 : 3 : 6 would cost 8.5 per cent. of the total cost per yard of concrete.

In case of more intricate reinforced concrete work, as beams and girders, the price will readily run up to \$25 a yard in place, and oftentimes much more; but assuming it does not cost any more than \$25 a yard, the cost of the cement in the 1 : 2 : 4 mix would be 7.4 per cent. of the total cost per yard of concrete; the cost of the cement in the 1 : 3 : 5 mix would be 5.7 per cent. of the total, and of the 1 : 3 : 6 mix, 5 per cent.

On the basis of that showing, there is very little inducement to skimp on cement, it seems to me. The additional factor of safety cannot be overlooked, because I don't care how well the job may be organized, or what attention may be given to it in the way of inspection, inequalities will creep in, and that personal equation should be limited just as far as possible; and if that can be done to a large extent by the addition of a small amount of cement at a nominal cost, it is a pretty good step to take.

I believe this, that the time is practically here when mechanical mixing will be insisted upon on any important work of any kind. Hand mixing of concrete has come to be such a perfunctory operation, attended with so many ragged results, that it really should not be permitted on any job of any importance. I believe engineers generally are coming to recognize that. Of course, if it is a small job, involving a small quantity of concrete, it would be a hardship to bring on to the job a mechanical mixer. But a job requiring anything from 500 yd. of concrete up is well justified in having a machine mixer on it.

Another thing which I think is well worth drawing your attention to is the fact that if you want a perfectly mixed concrete, a concrete of such consistency that the aggregates cling together, that is of a mushy consistency and does not separate

on handling, you don't want too much water in it. You want it of a gelatinous nature. You want concrete that can be tamped; you can't tamp water. But if you get it of a gelatinous nature that will cling together, put it in your forms and ram it lightly, or even tread it in with the feet of the workmen in the forms, and you have a concrete that in strength and density is a very superior concrete. And further than that, it develops a strength in the mortar, which, of course, is the strength of the concrete, that you can't get in any other way. Take the prolonged mixing in the laboratory of 1 : 3 mix; it has between 1½ to 2½ min. on the slab. If the batch is held in the mixer only a few revolutions more, you will have, as a rule, better concrete.

MR. NEWMAN. — In reference to the use of clay in concrete, I can give an instance where sand containing clay was used in preference to other sand. That was in lining a canal in California. Sand containing clay not exceeding 10 per cent. was preferred on the job and gave good results. The canal was 12 miles long and was lined throughout with concrete, and in connection with this work quite a bit of testing with clay mixtures was carried on. We found that with several sands we could add 15 per cent. of clay without reducing the strength at all.

MR. SHERMAN. — In reference to adding clay to cement, I wish to emphasize the fact that laboratory tests on these are really not entirely satisfactory. Clay can be pulverized and mixed with cement and sand and thoroughly mixed. Clay as it occurs in natural sand is lumpy, and even though it is worked a great deal, these lumps will still remain as lumps and are just so many weak spots in the mortar.

MR. THOMPSON. — I happen to have a record right here of Philadelphia sand. Before washing it contained 6 per cent. that passed the 200 sieve and gave a strength of 200 lb. per square inch. It was a fine sand. After washing it gave a strength of 150 lb. per square inch. The clay was in its natural condition, and yet it did in that case increase the strength of the sand.

THE CHAIRMAN. — I would like to ask Mr. Worcester whether he still thinks a 70 per cent. requirement on sand briquettes is a proper requirement, or whether he would use some other figure.

MR. WORCESTER. — That figure seems to me to be very satisfactory. I have no doubt that sand which develops 70 per cent. of standard sand is good enough. I don't think there is any dangerous percentage of organic matter in it. I wouldn't

know which way to change that, whether up or down, in order to get more satisfactory results.

MEMBER. — What do you call standard sand?

MR. WORCESTER. — I think it is generally recognized that Ottawa sand is standard.

THE CHAIRMAN. — I remember one instance in which a gentleman present had a share where the cement passed a well-known testing laboratory belonging to the government and yet failed to succeed in a certain piece of work in which the gentleman to whom I am addressing myself had a hand, and where other cement made quite a success. I would like to ask him if he discovered what the difficulty was.

MR. WASON. — My solution was the quick-setting cement. The time between mixing it on the work and getting it in place was a matter of about 15 min., whereas in laboratory work the briquettes are gotten into place in 3 or 4 min. The time of initial set was about 10 min. So the conditions which made the concrete fail on the work did not show up in the laboratory, where the initial set was not broken.

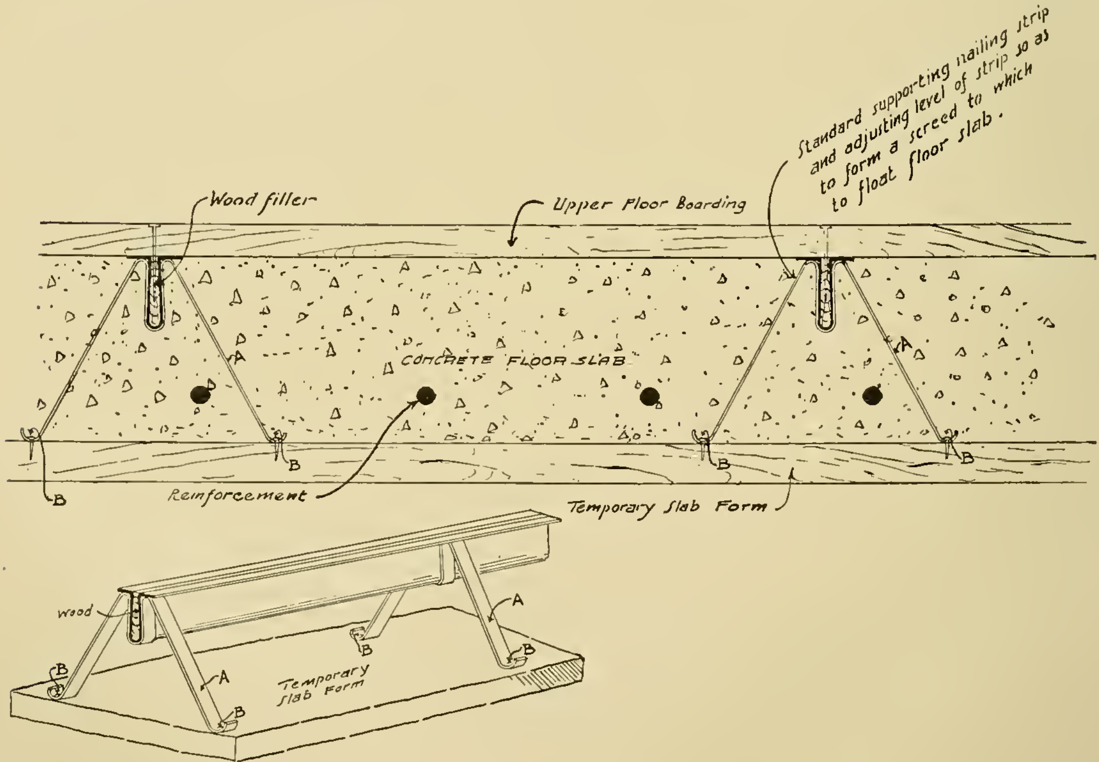
[NOTE. — Further discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by February 1, 1910, for publication in a subsequent number of the JOURNAL.]

METAL SCREED FOR CONCRETE FLOOR SLAB.

By Benjamin Fox, Member Boston Society of Civil Engineers.

[Read at an informal meeting of the Society, May 12, 1909.]

I want to submit for your criticism a metal floor screed designed as a substitute for the wood floor screed that is usually put on top of structural concrete floors. This screed is designed to set parallel with the reinforcement and flush with the upper surface of the structural concrete floor, supported every 2 or 3 ft. by a ribbed metal support "A," that is made beveled in at the top to hold the screed up in position and at the same time prevent it from working up with the tamping of the concrete floor. There are holes in this ribbed piece at "B" for tacking to the form. When in position, the screed also forms a true line for floating the structural concrete to. I will read over the good points I believe it has and leave your criticisms to bring out the bad ones.



The matter of end joints in the wood floor in using a square-edge floor is provided for by cutting the end joints at an angle of 60 instead of 90 degrees; and in the event of using a matched floor this cutting would be unnecessary. I started on this screed on account of the many objections I found among mill owners, who objected to the dust from concrete floors, and among employees, who objected to working on cement floors. This screed

is made of 22 gage metal and is stiff enough with these ribbed supports, about 2 ft. on centers, to take care of any buckling that might occur. My idea is to place the screeds 2 ft. on centers for nailing, instead of the regular 16 in. at which the wooden screeds are put on. Where a wood floor is a necessity, it saves in the height of the building. The thickness of a wood screed is 2 or 3 in., and on a ten-story building that means 20 to 30 in. saved in the height of the building, with a proportionate saving in the cost. There is no question about its staying where it is put, or of the floor staying where it is laid; this is not the experience with wood screeds. With the ordinary wood screed any warping of the upper floor will twist the screed. Another thing in its favor is that a square-edge floor can be used with this without the fear of the dusting through of the concrete underneath. With the square-edge floor and the wood screed, the working of the wood floor will powder the cinder concrete fill and let it dust up through the square-edge floor. The laying of a new floor in the place of an old one in which the wood screed is used is quite an undertaking, involving the tearing up of the screeds. With the metal screed it is only a case of taking up the floor and laying another one in its place. Another thing is the accurate placing of machinery on this screed. Many owners find it hard to locate machinery before the building is complete. With the wood floor nailed in this metal screed the machinery can be expansion-bolted through the floor into the concrete and moved around in any location afterward and expansion-bolted through the floor.

This screed is to run parallel with the reinforcement. The question may come up of the weakening of the slab by the lessening of the cross-section of the slab. But it seems to me it would only crack at such places as an expansion crack would occur in any case. As an illustration of the holding power of the nails, I will drive a nail into this sample which I have brought along. I think you can judge by the sound of the driving of the nail into the screed that it will hold.

There is one thing I did not speak of. I provide in this beveled space for a wood filling piece, and instead of depending entirely on the gripping of the nails on the sides of the beveled screed, I fill the space enclosed by the metal with a wood strip and the nail goes into it. This wood strip prevents the cement grout getting in the space. I tested the holding power of those nails and found it very much stronger than that of the nails going into a wood screed. I think those are all the points I want to make.

[NOTE. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by February 1, 1910, for publication in a subsequent number of the JOURNAL.]

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A MODERN BOILER SHOP.

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THE design of a factory for building steam boilers and doing the kind of sheet metal work allied thereto is not as intricate a problem as that of most other lines of manufacture. There were some interesting features, however, connected with the building of a recent plant that may be of service to others. As an illustration of a modern factory of this kind, this description of the Heine Safety Boiler Company's new shop at St. Louis, Mo., is presented.

GENERAL PLAN.

The property on which the shop is located lies at the intersection of East Marcus Avenue and the west belt of the terminal railway, a double track main line. In shape it is a trapezoid, one end being perpendicular to the sides, the other being at an angle of about 45 degrees. The four sides are, respectively, 259 ft., 512 ft., 771 ft., 836 ft., an area of 6.5 acres. It is along the oblique side that the railroad passes, Marcus Avenue being the boundary of the short side. A small stream meanders approximately on the railway property line. (Fig. 1.) The original surface of the ground sloped from an elevation at the creek bank of 24 ft. above the city datum to 67 ft. at the inner corner. The grade was fixed at 47 ft., that being the elevation of the railway tracks. To prepare the ground for building it was necessary to excavate the higher and fill in the lower portions of the site. There was just about enough material to fill in as much

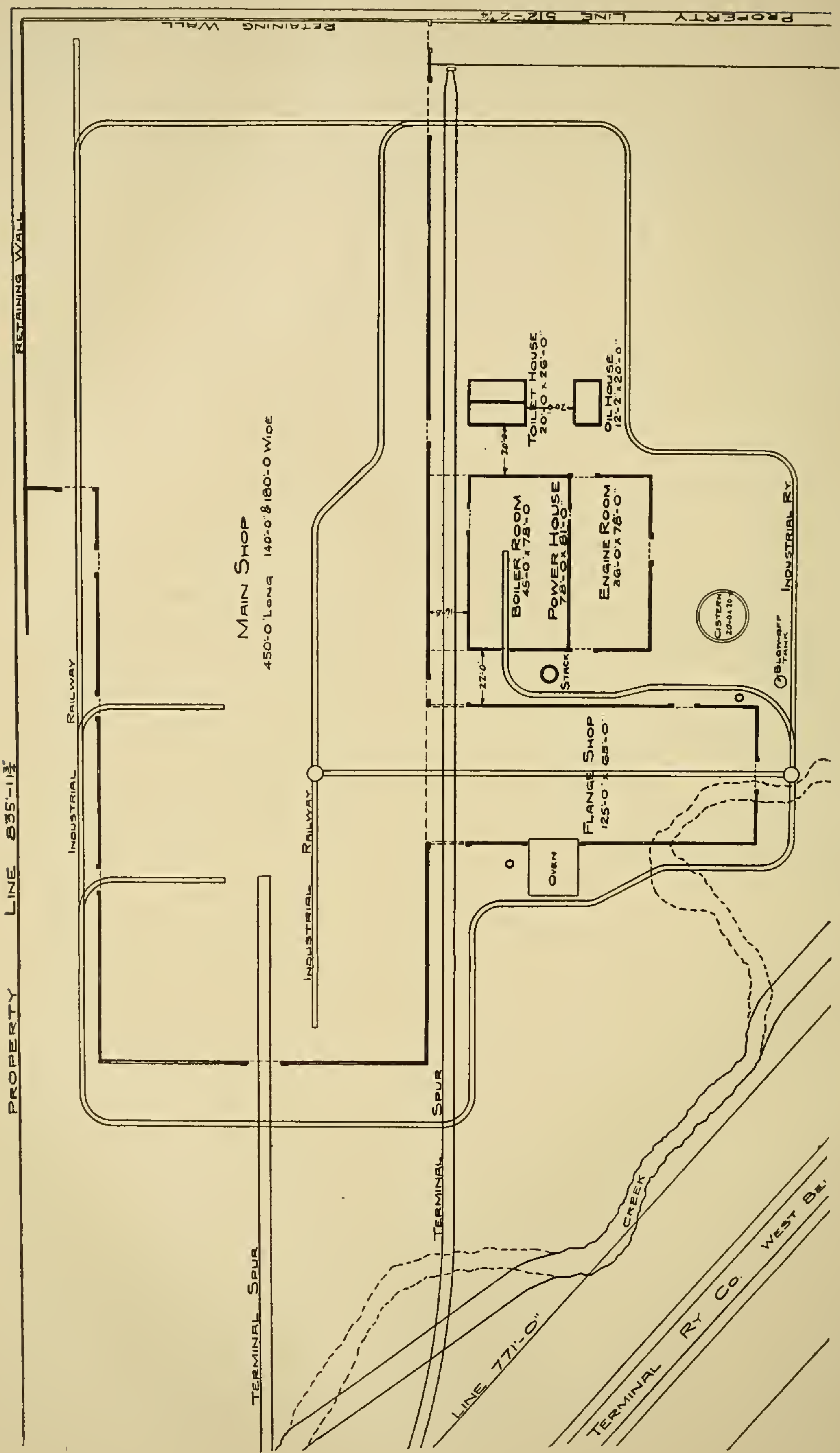


Fig. 1. General Plan.

of the lot as was required for immediate use, leaving a considerable area for the future disposition of cinders, etc. The stream was straightened in two places. A large municipal trunk sewer will soon be built along its course, after which the entire area will be available for such use as may be desired.

A reinforced buttressed concrete retaining wall with a maximum height of 19.5 ft. above grade at the corner and stepped down on the end and side, following the slope of the hill, is built 4 ft. inside the property line so as to keep the wide footing within the site. This wall forms a part of the end and side of one of the buildings.

The buildings consist of a main shop, flange shop (which is a wing of the main shop), power house, toilet and wash house, oil house and general office, totaling about 2.5 acres of floor space. The relative locations are shown on Fig. 1.

The shape of the property made the location of the switch connections simple and convenient. They enter with long radii curves, becoming tangents parallel to the buildings before reaching them. At present there are two switches, one of which enters the main shop and is the shipping track; the other passes alongside of the main shop between it and the flange shop and power house and is the receiving track. It is anticipated that another switch will be placed along the opposite side of the main building when conditions demand. A 100-ton 42-ft. extra heavy Howe track scale is located on the railway right-of-way near the connection to the main track. The office building is on the opposite side of the property facing Marcus Avenue, far enough away to avoid serious interference from the noises of the shop.

In general, the raw material is received at the far end of the large building, that being the storage space. During the manufacturing processes it passes without reversal to the opposite end, where the completed boilers are stored and shipped. Tubes, not being needed until boilers are assembled, are received and stored at this end. The whole floor area of both main and flange shops is served by large or small traveling cranes, while a 24-in. gage Koppel industrial railway completely encircles the structures, with connections in the interior, so that the handling of material of all kinds may be carried on with the least expenditure of time and energy. A roadway leads from Marcus Avenue into the receiving end of the main building. A portion of the interior of this building is partitioned off for a machine shop to do the little work of that nature required in the manufacturing processes and to care for the ordinary repairs and maintenance of the plant.

Three sources of power for the operation of the equipment are used — electric, hydraulic and pneumatic. All the generating machinery is located in the power house, which is placed in close proximity to the hydraulic and pneumatic tools, in order to reduce the length of the transmission lines, a saving both in first cost, frictional losses and maintenance. The great majority of the tools are electric driven by individual Wagner motors wherever practicable.

It is believed that the buildings as erected are amply large for some years of growth, so they are built with permanent ends; but, when conditions demand, the main shop may be extended toward the railway and the flange shop toward Marcus Avenue. Also a wing or separate buildings can be built along the rear end of the lot as an extension of the main shop.

As far as practicable all water is saved, to effect which a drainage system is provided into which all rain water from the roofs, as well as the clean waste from manufacturing processes, is discharged. This system discharges into a large cement-lined cistern 20 ft. diameter by 20 ft. deep near the power house. As the only source of water supply is from the city mains, this arrangement effects a very appreciable economy.

Type of Building.

The several buildings are all of the same general type, all structural details being standardized as far as practicable. At the outset it was determined to eliminate the fire hazard, and to build durably and yet have a maximun of natural light in the interior, which meant large window space. Steel frame structures with outside walls of brick and reinforced concrete slab roofs were accordingly adopted, with full-length monitors in the middle in order to obtain additional light and ventilation. About 75 per cent. of the vertical areas exclusive of the retaining walls are glass. One size of window pane is used throughout, this being a commercial size, 12 in. by 16 in. The advantage of this will be appreciated when it is understood there are over 22 000 panes in the several buildings. Wood is used only for window and door frames and doors, the machine shop and sheet iron shop floors.

Construction.

Main Shop.

This building is 450 ft. long by 143 ft. wide for 250 ft. of its length, and 180 ft. for the remaining 200 ft. It is of this latter

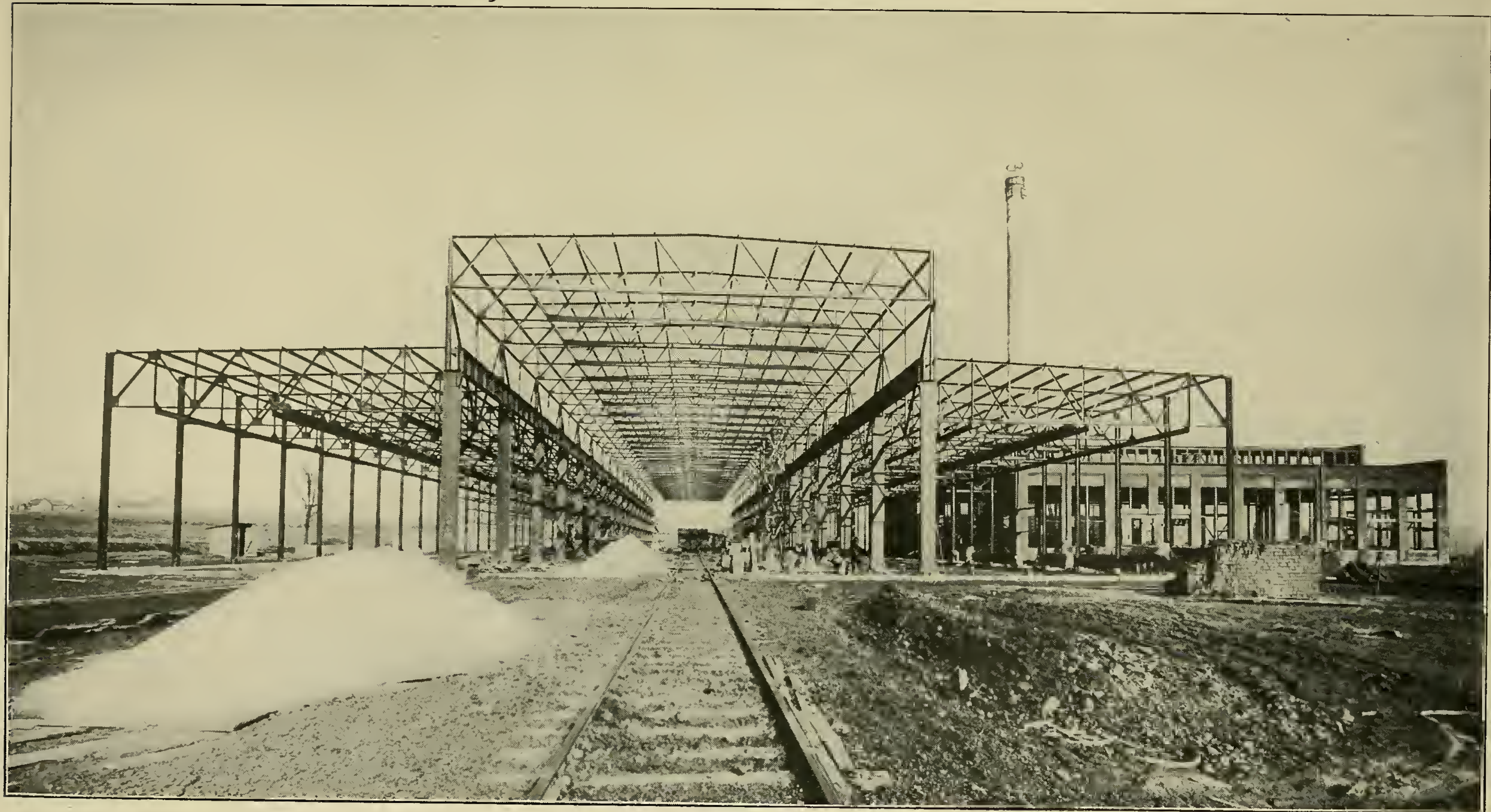


FIG. 2.

part that the retaining walls form one side and end. The narrow portion is divided into three longitudinal bays, the middle one being 60 ft. wide, and the two side ones 41.5 ft. The increase to 180 ft. is made by the addition of a fourth bay of 37 ft. The design of the steel frame follows standard practice, being calculated for the dead and live loads imposed by the roof and traveling cranes, the runways for which are 9-in. I-beams hung to the lower chords of the roof trusses, with the exception of the large crane way, which is carried directly on columns. The roof trusses are spaced 12.5 ft. centers, carried on the columns forming the bays. The columns of the central bay are spaced 25 ft. centers longitudinally, 60 ft. transversely, and carry the 25-ton traveling crane way. The spacing of trusses thus provides stiffeners at the center points of the main crane runway and provides spaces of only 12.5 ft. for the support of the smaller crane runways in the side bays. The roof of the middle bay is 14 ft. higher than that of the side bays, thus forming the monitor in which the principal crane runs. (Fig. 2.) About the middle of the side toward the power house is the riveting tower, 100 ft. long by 24 ft. wide, its roof being 55 ft. above the floor. The steel work of this tower is framed into that of the building proper.

The outside walls are of brick with concrete footings and completely enclose the outer steel columns. The outside columns carrying the trusses of the fourth bay rest on the retaining wall, which also serves as a foundation for the brick walls that close the end and side of the building at these points. Practically all the windows in the walls are 9 ft. 8 in. wide by 17 ft. 5 in. in height, this being the standard size for all buildings. The stone sills of the windows are 3 ft. 2 in. above the floor line, while the tops are practically at the height of the lower chords of the roof trusses. Each of these openings has two vertical rows of three sashes, each 3 ft. 5 in. by 5 ft. 10 in. high, and of the same construction. The middle sash is stationary; the upper and lower sashes are arranged so that they can be raised and lowered vertically. They counterbalance each other through steel chains over special pulleys at the top of the window frames, so that by raising the lower sash any degree of opening of the windows from nothing to two thirds is very easily and conveniently accomplished by one man and from the floor level. The windows over the retaining walls at the rear end and side are arranged so as to utilize as much of the space between the top of the wall and the roof trusses as is practicable.

Both sides of the monitor are practically all window space

there being two rows of sashes which are also each 3 ft. 5 in. by 5 ft. 10 in. in size. Those in the lower row are stationary; those in the upper row are pivoted at the middle so that they can be opened for ventilating purposes. One side of this monitor is unbroken, but the opposite side is divided into two sections by the riveting tower. Double rows of windows arranged similarly to those in the monitor are placed in both sides and ends of the tower. All the pivoted windows in the unbroken side of the monitor are operated in two sections of equal length, each by means of a single Lovell window operating device. The two sections on the opposite side are each operated by a single device of the same type.

The upper row of sash on two sides of the riveting tower is likewise pivoted and operated. (Fig. 5.)

The standard size of door opening is 9 ft. 8 in. by 12 ft. high, closed by two equal swinging doors, one of which contains a small door to permit employees to pass easily into and out of the building. Above these doors are two stationary window sashes of the standard size. In the receiving end is located a special door opening 22 ft. 2 in. wide by 20 ft. high. Through this is carried a transverse crane way 18 ft. $8\frac{1}{4}$ in. span projecting outside of the building over the receiving track, the outer end being carried by "A" frames. (Fig. 3.) This connects with the longitudinal cranes in the inside, thus permitting the unloading of material from cars expeditiously and cheaply. This large opening is closed by means of a special variety rolling steel door carried on trolleys which run on the crane way. The carriage for this door is covered with a hood which entirely closes the opening above and between the beams when against the building, the door and its rolling mechanism being suspended below the crane way beams. When in this position the rolling door lowers into the guides provided at the side, and when it is entirely rolled up the whole carriage may be moved to the outer end of the crane way, thus giving an unobstructed passage for the traveling crane and at the same time preserving the continuity of the crane way. This special door was made necessary because of the extreme size of the opening and by the governing conditions which rendered any other type of door impracticable. The door and carriage are operated by means of gears and hand chains. The hood so protects the mechanism of the carriage and the door when it is rolled up that it can be left exposed at the outer end of the crane way without harmful results. Although the door is of large dimensions, it can be

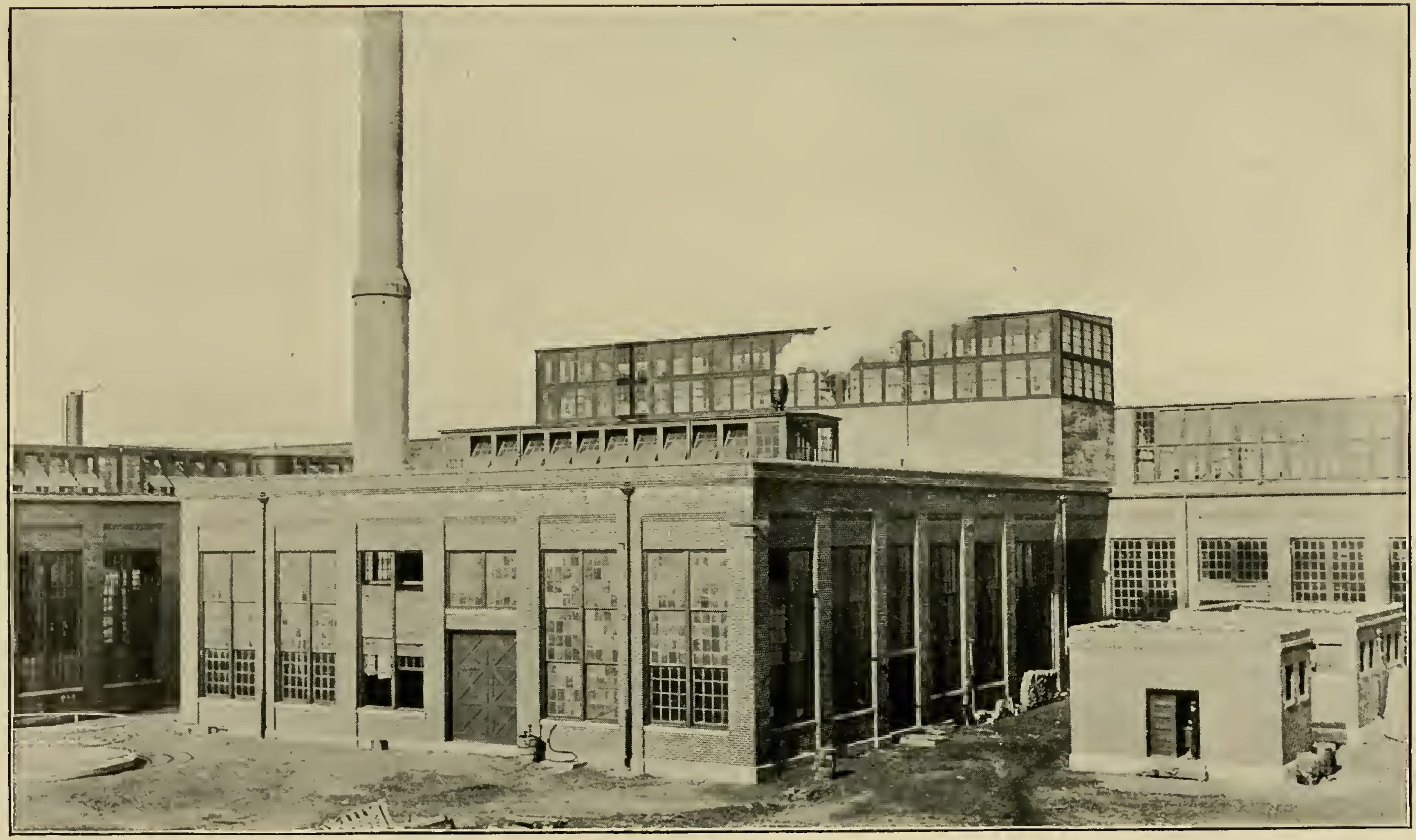


Fig. 5.

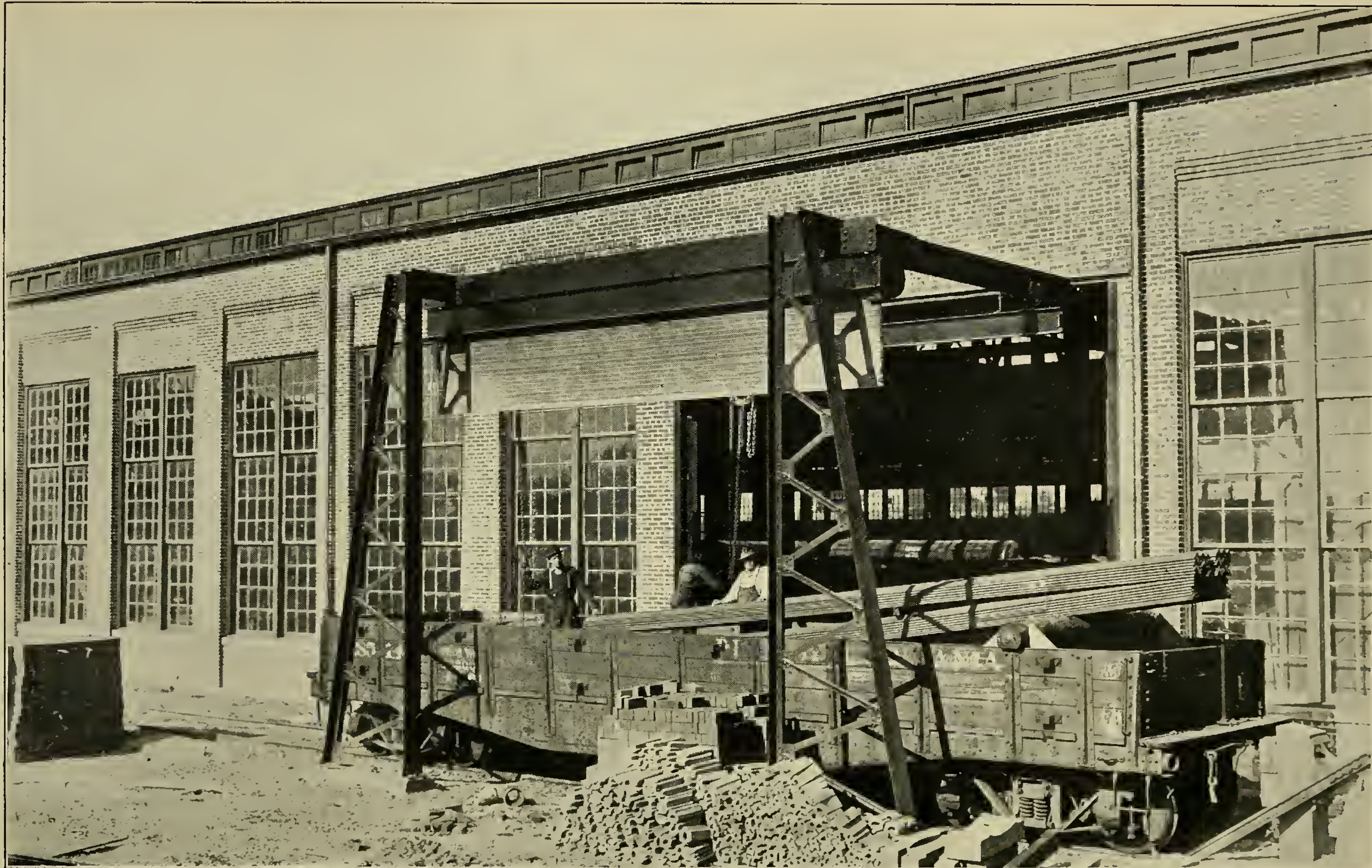


FIG. 3.

opened and closed by one man, even in a high wind. A door 14 ft. by 16 ft. high is provided in the end of the fourth bay to permit the placing of cars inside the building when the proposed switch on that side is put in.

The roof is a $2\frac{1}{2}$ in. concrete slab reinforced with wire mesh and carried by 6-in. I-beam purlins placed 5 ft. centers on the top chords of the roof trusses. This is covered with two-ply tar felt and gravel laid in hot asphalt. Two transverse expansion joints, dividing the roof into three equal sections 150 ft. long, provide for changes in dimensions due to temperature. These joints are flashed with copper. The gutter troughs and down spouts are of 16-oz. copper, supported by $\frac{5}{8}$-in. by $1\frac{1}{2}$-in. galvanized iron brackets set in the brickwork. Ample expansion joints are provided in the troughs to prevent buckling or breakages. Each down spout connects with a cast-iron shoe to the underground drainage system so that rain water acts as an auxiliary water supply.

The exposed sides of the riveting tower are 4-in. reinforced concrete slabs to the height of the monitor roof, above which are the windows.

The machine shop is formed by partitioning off a space 46 ft. by 62 ft. with corrugated iron attached to angle iron frames fastened to the building columns. This partition, however, is largely window space.

Where the flange shop joins the main building the wall has been omitted, giving free communication between the two.

The floor will ultimately be of cinders, with a heavy residuum oil binder and compacted by rolling. At present it is the natural clay. As before stated, the machine and sheet iron shops have a heavy plank floor. The shipping track at the front end enters through a sliding door 14 ft. by 16 ft., and holds two cars inside the building and bisects the testing floor, which is a brick pavement 62 ft. by 76 ft. laid in cement on a concrete base, draining into four sewer inlets which connect with the drainage system, thus returning the testing water to the cistern.

Flange Shop.

This building is 62 ft. 4 in. wide by 144 ft. long, the construction being similar in every respect to that of the main building, to which it is connected, the end wall being omitted so that the two structures are practically one. The steel frame consists of a row of columns in each side wall, spaced 25 ft. centers, which carry the roof trusses. There are intermediate trusses spaced $12\frac{1}{2}$ ft. centers. These trusses span the entire

width of the building, leaving the floor area unobstructed, and carry two parallel traveling crane ways of 9-in. I-beams with 18 ft. 8 in. span, hung from the bottom chords, below which there is a clear height of 20 ft. This building has a monitor 13 ft. wide by 9 ft. high, made of light frames supported in the middle of and by the roof trusses. The window arrangement is exactly the same as in the main building except that the monitor has but one row of pivoted sashes on each side operated by a Lovell device. Door openings 16 ft. 10 in. wide by 20 ft. 9 in. high are placed in the side walls at the ends next the main building through which the receiving switch passes. These openings are closed by Kinnear rolling steel doors so that cars can be operated through the building on this track.

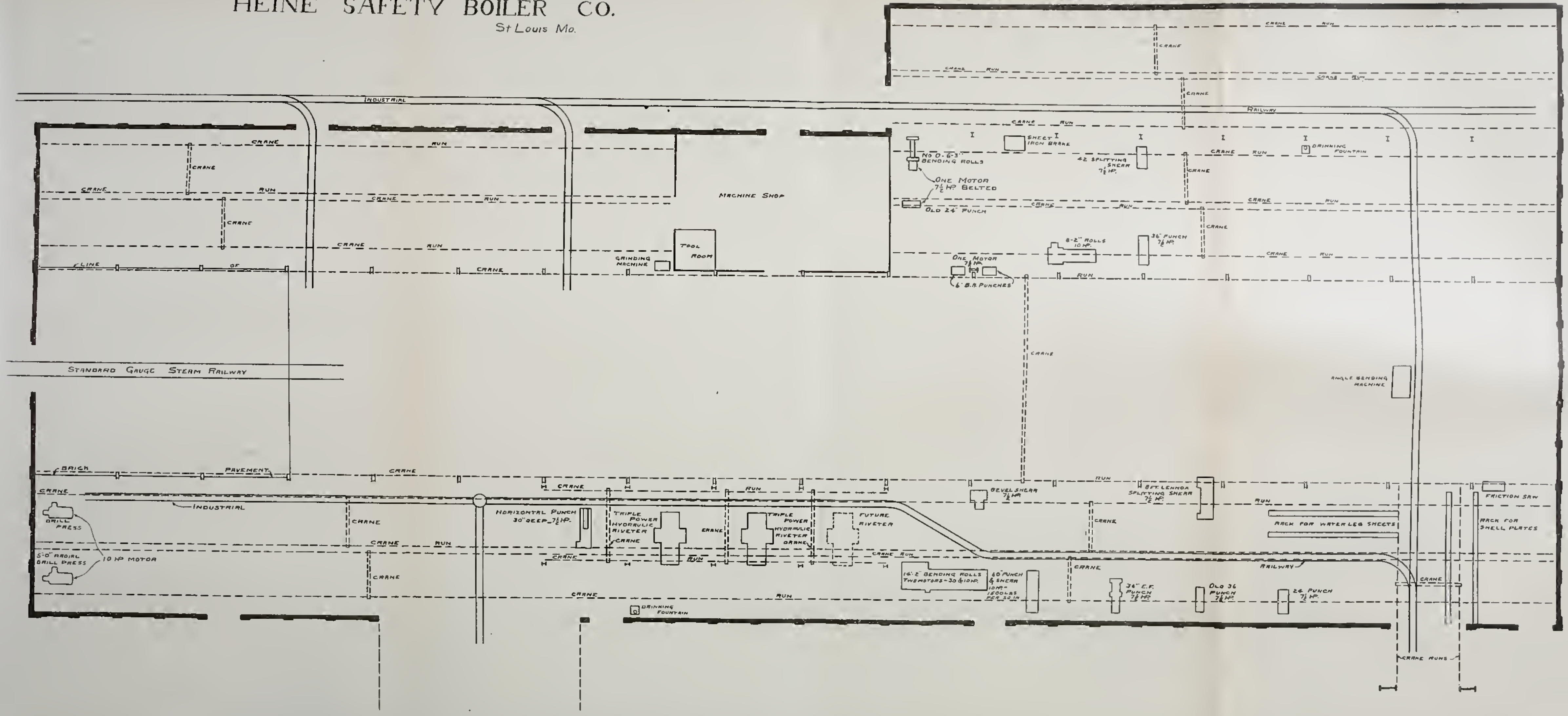
In one side of the building an opening is left in the wall for the large heating furnace, which is housed in a small steel frame structure placed against and outside the wall.

One of the outer corners of the flange shop is over a fill and a part of the original creek bed. This made it necessary to carry concrete footings down 24 ft. to bed rock. These footings are in the shape of concrete columns, carrying reinforced concrete beams just below the floor level, which, in turn, carry the steel frame columns and the brick walls. A standard door is in the middle of the outer end.

Power House.

This building is 75 ft. wide by 79 ft. long, being separated by a distance of 22 ft. from the flange shop and 16 ft. 10 in. from the main shop. In the main, its construction is the same as that of the other two buildings (Fig. 5), the main difference being that it is divided into an engine room, 34 ft. 7 in. wide, and boiler room, 42 ft. 11 in. wide, by a brick wall in which is located a row of columns carrying the abutting ends of the roof trusses. The monitor, 13 ft. wide by 50 ft. long, with windows similar to those heretofore described, is half over one room and half over the other, the partition wall extending to its roof. The middle row of columns and the outer row carry the runway of an overhead traveling crane serving the engine room. The roof is continued over the space between this and the main building in order that coal cars may be unloaded without interference by the weather. The entire floor of this building is at the same level, made of concrete and provided with necessary pipe trenches, which are covered with iron plates. The outer wall of the boiler room is carried up solid to the coal holes, a height of 8 ft.

PLAN OF MAIN SHOP
Showing arrangement of Tools and Craneways.
HEINE SAFETY BOILER CO.
St Louis Mo.



The coal holes are opposite the boilers and are 3 ft. high and 10 ft. long, with heavy iron frames set in the brickwork and closed with iron doors. Above these coal holes is a row of windows.

Toilet and Wash House.

This is located 16 ft. 10 in. from the main shop and 20 ft. from the power house, where it is accessible with a minimum loss of time. (Fig. 5.) It is a one-story brick building, 20 ft. by 26 ft., with a concrete roof and floor and divided by a brick wall into two rooms about 9 ft. wide, one of which contains ten wash down closets and an iron enameled urinal, both with automatic flush; white enameled wash sinks with numerous hot and cold faucets are in the other room. A galvanized house boiler, heated by exhaust steam, furnishes a supply of hot water. Lighting is by small windows near the top of the walls. The sewerage is carried by a sanitary sewer to the creek at the far corner of the lot.

Oil House.

This is a one-story brick building 12 ft. by 20 ft., with a concrete roof and floor, located 20 ft. from the toilet house and 20 ft. from the power house, from which it can be quickly reached. It is intended solely for the storage of inflammable liquids, etc. (Fig. 5.)

Equipment.

Main Shop.

In this part are stored all the raw material, supplies, etc. Most of this storing is done at the extreme rear end and side where there is the least light, yet where it is accessible and easily removed to any point where it may be needed. A 3-ton Yale & Towne traveling crane on the transverse crane way heretofore mentioned serves the delivering track and places the boiler plate, which is the heaviest material received, directly into a series of racks that hold the plates in a vertical position so that any plate may be withdrawn without unnecessary handling. The side bays are each served by four 3-ton 14-ft. Curtis traveling cranes, with hand-operated triplex blocks running on two adjacent parallel crane ways in each bay hung to the bottom chords of the roof trusses.

This shop contains tools as follows. The motor sizes given indicate that the machine is driven by an individual motor.

1 Ryerson high-speed friction saw, 30 h. p. motor.
1 24-in. Kraut punch, $7\frac{1}{2}$ h. p. motor.
1 36-in. Cleveland punch, $7\frac{1}{2}$ h. p. motor.

1 8-ft. Lennox splitting shears, 7½ h. p. motor.
1 60-in. Cleveland punch and shear, 10 h. p. motor.
1 Lennox rotary bevel shear, 7½ h. p. motor.
1 14-ft. Hilles & Jones bending roll, 10 h. p. and 30 h. p. motors.
2 100-ton Woods triple power hydraulic riveters.
1 30-in. Long & Allstatter horizontal punch, 7½ h. p. motor.

The three last machines are located under the riveting tower and are served by three 10-ton Wood hydraulic tower traveling cranes with 40 ft. lift and 20 ft. 7 in. span.

One unoccupied section in this tower provides for an additional riveter.

2 5-ft. radial drills belted from a shaft driven by a 10 h. p. motor, supported overhead on a bracket bolted to the wall.
1 Wood portable hydraulic riveter, which is handled by the hydraulic hoist in the 30-in. horizontal punch tower.
1 25-ton Pawling & Harnishfeger electric traveling crane, 26½ ft. lift, 60 ft. span, with 5-ton auxiliary hoist, with General Electric motors for all movements.

An outfit of pneumatic calking, riveting and chipping hammers.

Also the following sheet iron working tools:

1 angle-bending roll, 10 h. p. motor.
1 sheet iron break, 7½ h. p. motor.
1 42-in. Lennox rotary splitting shears, 7½ h. p. motor.
1 36-in. Kraut punch, 7½ h. p. motor.
1 8-ft. Hilles & Jones bending roll, 10 h. p. motor.
3 6-in. Cleveland punches belted to a countershaft driven by a 7½ h. p. motor.
1 6-ft. Hilles & Jones bending roll.
1 24-in. Long & Allstatter punch.

These two latter are belted to a countershaft driven by a 7½ h. p. motor.

The machine shop equipment is mainly belt-driven by a 20 h. p. motor through a line shaft. There are four lathes of various sizes, one shaper, one universal milling machine, three different sizes of radial drills, one planer, one heavy duty motor-driven boring mill, one double-head bolt cutter, two pipe threading machines, a combination grinder, one wet grinder.

In the flange shop are:

1 180-ton 60-in. Wood hydraulic punch and shear.
1 130-ton 60-in. hydraulic sectional flanging machine.
1 1100 lb. Bement Niles steam hammer.
1 10-in. Long & Allstatter horizontal punch, 7½ h. p. motor.
1 250 lb. Bement Niles steam hammer.

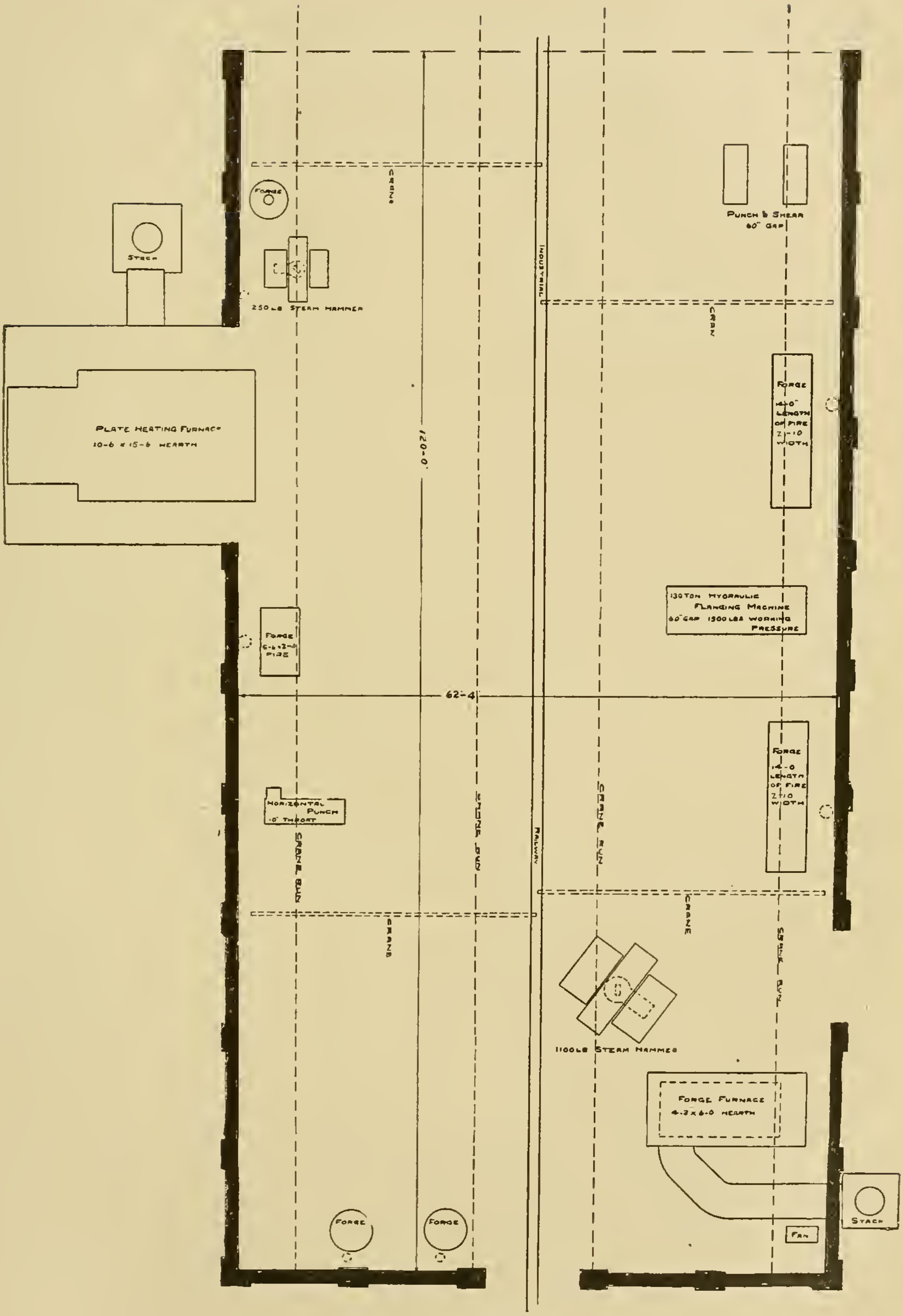


FIG. 4. PLAN OF FLANGE SHOP.
Showing arrangement of tools and cranes.

2 2 ft. 10 in. by 14 ft. hearth open forge fires.
1 2 ft. 10 in. by 6 ft. hearth open forge fire.
1 4 ft. 3 in. by 6 ft. hearth reverberatory forge furnace.
1 10 ft. 6 in. by 15 ft. 6 in. hearth reverberatory plate heating furnace.
3 blacksmith forges.
1 $24\frac{1}{2}$-in. motor-driven blast fan and pipe connections to forges.
1 cast-iron plate straightening bed and roller.
Complete set of cast-iron forming blocks, dies, etc., to suit the special requirements of the type of boiler built by this company.
4 3-ton Curtis traveling cranes.

All the small traveling cranes in both shops on adjacent parallel tracks overhang their runways far enough so they can be locked together and the trolley run from one to the other. (Fig. 4.)

All the steam, hydraulic and air pipes and electric wires are brought over from the power house in covered trenches and are so arranged that they can be easily drained in cold weather to avoid all danger of freezing. The air pipes have numerous connections at convenient points throughout the main shop, flange shop and machine shop.

Power House.

The boiler plant consists of three Heine boilers of 250 h. p. each, set separately. Two of them are provided with Heine superheaters of two different capacities. (Fig. 6.) They are all fired by hand and have flat shaking grates. Back of the bridge walls of each furnace is a special fire brick wing wall construction for the prevention of smoke, which accomplishes the object very satisfactorily. The two boilers with the superheaters are set in brickwork in much the usual way. The third boiler has a reinforced cement setting with fire brick lining. This was tried as an experiment to determine the availability of concrete construction for this purpose, and with the expectation that it will be more durable than brick and less liable to the cracking that all brick settings are subject to. The three boilers differ each from the others in dimensions, and all are arranged so that measurements and observations of all kinds may be conveniently made.

The company has in view a great variety of experiments to determine questions now in doubt and to develop further improvements in boiler practice. This will account for the boiler capacity being greatly out of proportion to the rest of the

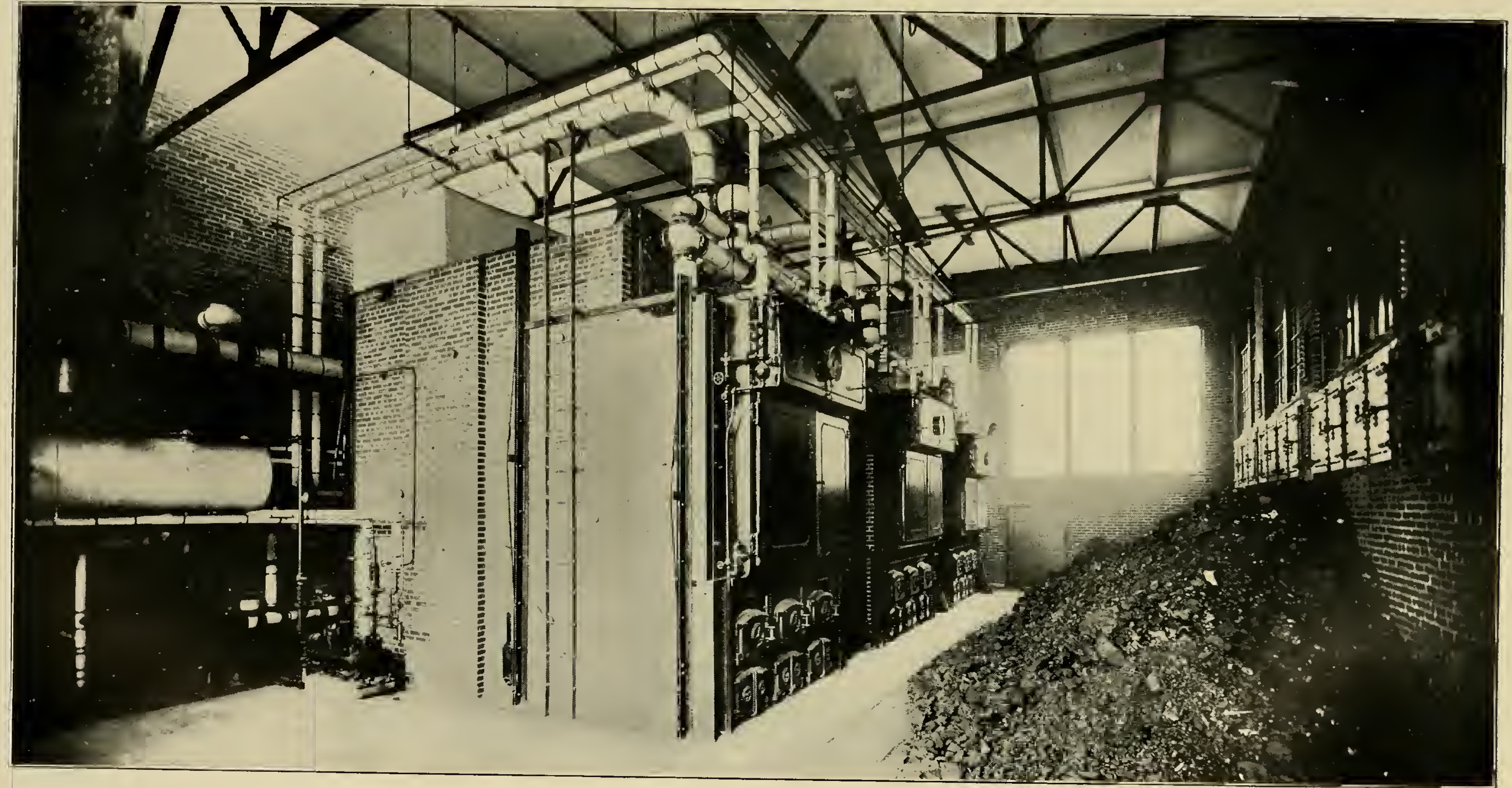


FIG. 6.

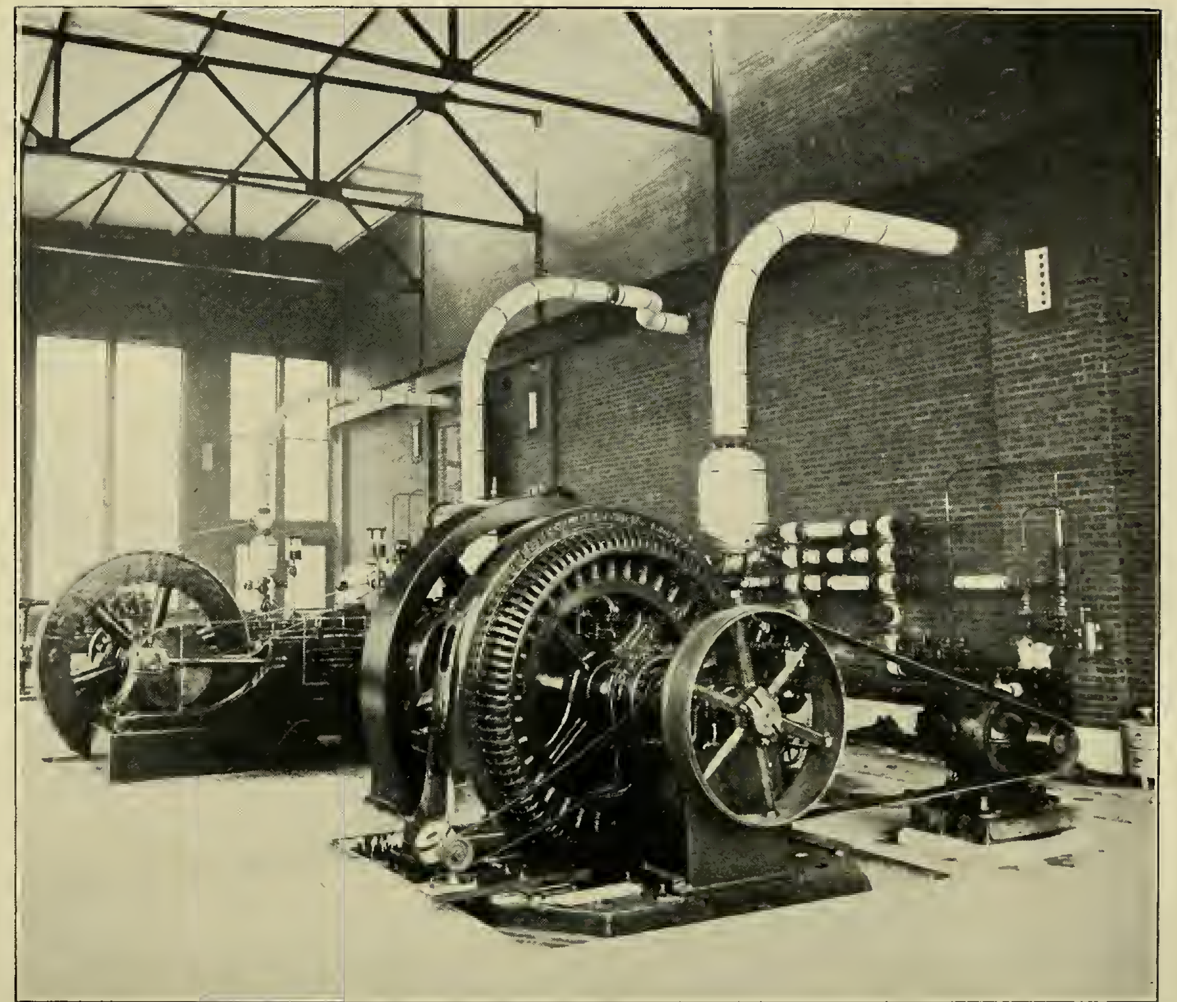


FIG. 7.

plant; one boiler will easily carry the load. A straight horizontal sheet-iron breeching connects the boilers with the chimney located in the space between the boiler house and the flange shop. This is a reinforced cement chimney 66 in. inside diameter by 147 ft. high, the foundation for which is 11 ft. deep and 22 ft. square at the base, a concrete monolith.

As the power requirements are not great, the installation of automatic stokers and coal and ash handling machinery was not deemed expedient. Coal is, therefore, unloaded by hand into the space in front of the boilers, which has a capacity of about two cars.

A Hoppes exhaust steam feed water heater, with a capacity of 15 000 lb. of water per hour, is placed on an iron support against the division wall. The air supply for the compressor is brought from the roof through a 12-in. sheet iron duct to an air washer placed behind the boilers. A small duplex steam pump delivers water from the cistern to the heater, being regulated by a Fisher governor. A boiler tester of the injector type supplies hot water under the required pressure for the hydrostatic test applied to all boilers before shipment. This testing can also be done by pressure from the hydraulic system, and through proper connections by the boiler feed pumps. An injector for feeding the boilers is provided for the use of the night watchman in order to avoid running the pumps.

All hot piping and the smoke flue are heavily covered with 2-in., 85 per cent. magnesium covering. Two openings 3 ft. wide and 7 ft. high are the only inside communications between the boiler and engine room and are closed by sliding wooden doors covered with sheet iron. One end of the boiler room serves as a workshop and has an enclosed dressing room and toilet.

The electrical energy is developed by a 162 h. p. 4-valve non-condensing Ball engine, 13 in. by 18 in., running 200 rev. per min. A 100 kw. 220-volt 3-phase 60-cycle Western Electric Company's generator is directly connected to the engine. An 11-kw. exciter is belted to a pulley on the engine shaft. The voltage is maintained constant by a Tirrell regulator mounted on the switchboard. All wires in the engine room are placed in conduits under the floor. The switchboard is completely equipped with all the measuring, controlling and distributing devices, and is divided into four panels, one for the generator, all current delivered being measured by a watt meter, two for the four power circuits, one for the six lighting circuits.

A Laidlow Dunn Gordon two-stage, compound, non-con-

densing air compressor is next to the engine. It has 12½-in. and 22-in. steam and 22½-in. and 14-in. air cylinders, with 18-in. stroke. Its capacity is 1200 cu. ft. of free air per min. at 100 lb. pressure when running at 145 rev. per min. 145 lb. steam pressure. It takes its supply from the air washer just the other side of the partition and discharges into a receiving tank 36 in. by 10 ft. standing nearby.

A Worthington duplex compound non-condensing pumping engine, with 14-in. and 22-in. diameter steam and 4-in. diameter water cylinders, 18-in. stroke, supplies the hydraulic system. Its capacity is 100 gal. per min. against 1500 lb. pressure, with 145 lb. steam pressure. A Wood hydraulic accumulator, 12 in. diameter of ram and 15 ft. stroke, loaded to give 1500 lb. pressure per sq. in., is located in one corner of the room. It is connected with an automatic controlling valve which shuts off the pump when the limit of lift is reached.

A 700 cu. ft. Norwalk air compressor, an old machine from the old shop, is located next the larger machine, and is connected to the same supply and discharge, but is intended only for emergency use. There is an additional space in the engine room for a duplicate generating set and also for another 1500 lb. hydraulic pump.

Two 7½ in. by 4 in. by 6 in. Blake duplex outside packed plunger feed pumps are placed against the partition opposite the heater and are controlled by Fisher governors. (Fig. 7.) The feed piping is in duplicate and so arranged that any boiler can be fed independently of the others and of the other pump. This is to permit the testing of any boiler without interfering in any way with the operation of the plant. The suctions of these pumps are connected to the heater, the city mains and the cistern. Means are provided for filling boilers directly with city water. The small pumps have a separate steam header so as to be independent of the main steam header.

A 10-ton Pawling & Harnischfeger hand-power traveling crane, with 33½ ft. span and 17½ ft. lift, serves the entire area of the engine room. Only the live steam pipes are exposed in this room, all others being laid in covered trenches.

Miscellaneous.

Artificial lighting is mainly by 10 flaming arc lights uniformly distributed through the shops. They are hung to clear the cranes in monitor and bays and in the latter are about 22 ft. from the ground. The engine and boiler room have each one

lamp of the same kind. In addition, each machine tool has one or more incandescent lights near the workman. Special six-light incandescent fixtures are recessed in the walls 10 ft. from the floor around the sides of both engine and boiler rooms, with switches in closed hand high pockets. The water and steam gage of the boilers each has a light on separate circuits for each boiler. No outside current is used for either lights or power, except for two arc lights for night use and for the office.

A boiler shop requires heating only in comparatively cold weather, say when the temperature falls below 45 degrees fahr. It is, therefore, unnecessary to heat it above that temperature at any time. Open salamanders, usually without means for carrying off the gases of combustion, is the plan most often used, but a better plan from every point of view has been here adopted. The main shop is provided with a sort of hot blast system, consisting of five sets of enclosed coils of ¾-in. pipe, each containing about 3000 sq. ft. of radiating surface. A motor-driven fan forces the air through the coils, discharging directly into the room in an opposite direction from the intake. These sets are distributed so as to give the greatest heating effect where needed. It is anticipated that the circulation thus created will be sufficient to make the temperature sufficiently high and as nearly uniform as is necessary. Exhaust steam is used, but whether there will be sufficient or not, and whether the system will be satisfactory, has yet to be determined. The machine shop, toilet house and office are heated by direct radiators. The flange shop needs no special heating, the fires there being ample. If there proves to be insufficient exhaust steam, live steam will be turned in through a reducing valve, provision for this having been made.

To provide cool drinking water in summer a special drinking fountain was designed, of which two are installed. This consists of a concrete-lined pit about 4 ft. by 6 ft. by 3 ft. deep, divided into two compartments, one 27 in. by 27 in., the other 18 in. by 37 in. The walls of the larger, which is the ice chamber, are built with air spaces. Near the bottom is a horizontal coil of 1¼ in. galvanized pipe, with a wooden grating above to hold the ice. A drain, the bottom of which is 2 in. above the top of the coil, carries the warm water into the other compartment, in which are the valves for shutting off the supply, etc., and from which all waste is drained into the drainage system leading into the cistern. Over this latter compartment is the hydrant, with a suitable waste pipe and perforated cover. About 300 lb. of ice

can be put in the chamber, which is covered with both a thick wooden and an iron lid. In hot weather the supply of ice lasts two days. Water from the city mains is used exclusively for drinking.

Although the buildings are free from fire risk to such an extent that it is considered unnecessary to carry insurance, there is more or less inflammable material around in the shape of boxes, barrels and other packing material, as well as wooden railway cars. A simple fire system was, therefore, installed. Six 2-in. fire hydrants are uniformly distributed through the main shop, with 100 ft. of canvas hose and nozzle suspended on holders at each. There are also three hydrants outside, two on the opposite sides of the front end of the main building and one near the oil house. The water supply is from the city mains and under a pressure of 60 lb., so no other source of supply for this purpose is necessary. In addition, there are nine Minamax non-freezing and twenty-four Johns-Manville dry powder fire extinguishers hung at numerous convenient points. This is supplemented by a city fire-alarm box on the outside of the power house.

Costs.

The land was purchased in the middle of 1907 and the general scheme worked out by the officers of the company in conjunction with Messrs. Lichter & Jens, consulting engineers, who drew the plans and superintended the work. Much of the preparatory drafting work was done prior to the time when the decision was reached to proceed with the building of the plant.

The actual construction was purposely undertaken at a time of business depression. So far as prospects for obtaining sufficient orders to anywhere nearly develop the capacity of the plant when completed, or soon thereafter, were concerned, there was little incentive to proceed. Owing, however, to the very limited building operations of this nature throughout the country at the time, it was certain that the first cost would be very low. Early in 1908, when materials were at their lowest prices, it was, therefore, determined to proceed, financial arrangements having been satisfactorily concluded.

The grading was done in June and July, 1908. A little more than 18 000 cu. yd. of earth was excavated at a cost of 16 cents per yard.

This and the retaining walls were executed by the Fruin-Colnon Contracting Company.

The steel work, amounting to about 790 tons, was furnished

by the Riter Conley Manufacturing Company at the rate of practically 2.6 cents per pound f. o. b. St. Louis. It was all inspected by the R. W. Hunt Bureau of Inspections and Tests before leaving the factory.

The erecting of the steel was done by the Midland Erection Company at the rate of $8.80 per ton. The general contract for the completion of the main shop, flange shop and power house was executed by the Fruin-Colnon Contracting Company.

The total cost of these buildings was $1.15 per square foot of floor area, excluding the retaining walls and grading, and $1.29 including those two items. This, of course, does not include any of the equipment.

[NOTE. — Discussion of this paper is invited, to be received by Fred Brooks, Secretary, 31 Milk Street, Boston, by March 15, 1910, for publication in a subsequent number of the JOURNAL.]

BOYLSTON STREET BRIDGE, BOSTON, FROM 1888 TO THE PRESENT TIME.

THE DESTRUCTION AND RECONSTRUCTION OF A BRIDGE SUBJECTED TO LOCOMOTIVE FUMES AND INCREASING STREET CAR LOADS.

By Frederic H. Fay, Charles M. Spofford and John C. Moses, Members Boston Society of Civil Engineers.

[Read before the Society, December 16, 1908.]

Introduction.

By Mr. Fay.

An account of the Boylston Street Bridge comprises the life history of a metal structure over a railroad, built partly of steel and partly of wrought iron, which in less than twenty years was practically destroyed, that is, rendered unsafe for further use, through the following causes:

(1) The corrosive effects of locomotive fumes.

(2) The increase in weight of street cars.

(3) Neglect to properly care for those parts of the structure most exposed to the destructive action of locomotive gases.

The fumes from locomotives are primarily responsible for the destruction of the bridge. If the structure had been over water, it is probable that, with a proper strengthening of the floor system, it would to-day be standing and safely carrying the increased loads, although with 50-ton street cars like those now in use on the Boston and Worcester line the limiting load for the original trusses would have been exceeded, and restriction of car travel would have been necessary.

The destruction of the floor system of the bridge was hastened by the increase in weight of street cars which crossed the structure upon two tracks in the middle of the roadway. The floor beams, designed before the advent of electric cars, were built to provide for a live highway loading of 80 lb. per square foot or a single 20-ton wagon. In their weakened condition these beams had to carry not only the usual highway traffic, but also cars up to 26 tons weight on both tracks. In many instances under this car loading the floor beams, which were double-webbed plate girders, had their top flanges and even a diaphragm connecting the two webs broken; and while the rusted floor beam, if un-

broken, might have carried ordinary travel for some years more, these broken beams had become unsafe for heavy teaming and positively dangerous for further use by the street cars then crossing the bridge.

Improper maintenance, that is, neglect to properly clean and paint the structure, no doubt hastened its destruction to some extent. As is usually the case, the metal work exposed to view above the floor, which didn't need the care, was kept well painted, while that beneath the floor surface was rarely or never touched, and in the struggle between the locomotive gases and the paint, the gases had the field practically to themselves after the original paint coating had been once broken through.

The history of the first Boylston Street Bridge forcibly illustrates the fact that in metal bridges over railroads in which parts of the metal structure, protected only by paint, are underneath the floor, it is practically impossible to properly inspect or maintain the structure except by completely removing the floor surfacing, thereby rendering all parts of the metal work accessible for cleaning, examination and painting.

To-day we have at the Boylston Street crossing two structures, one within the other: one to carry the loads upon the car tracks; the other to take the loads upon the sides of the roadway and the two sidewalks; both structures built with a view to permanency by having a minimum amount of metal work below the floor and that protected from the locomotive gases, so far as possible, by concrete.

In the following papers there will be given an outline of the construction and history of the original bridge and a description of the structures built by the Boston Elevated Railway Company and the city of Boston to replace it.

Description of the Original Bridge.

By Mr. Fay.

Boylston Street crosses the main line of the Boston & Albany Railroad at the extremely sharp skew of 71 degrees; that is, the angle made between the center line of the street and the railroad location line is only 19 degrees; and while the location is but 60 ft. wide, the distance across the location, measured along the center line of the street, is 176 ft., or nearly three times the width of the location. The street is 80 ft. wide.

When the first Boylston Street Bridge was built, in 1888, no part of the railroad location was available for piers or for erecting

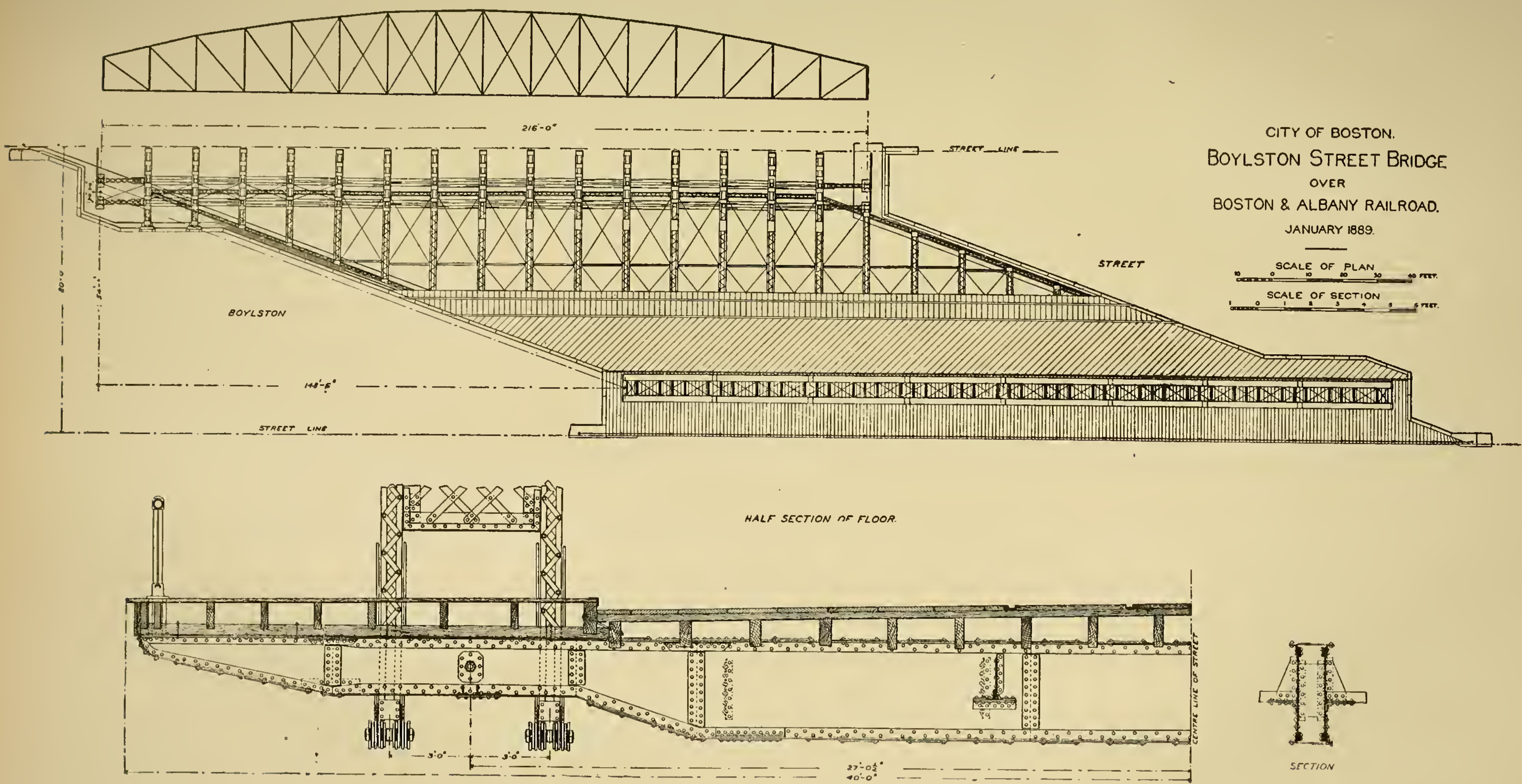


FIG. 1. GENERAL PLAN AND FLOOR SECTION OF ORIGINAL BRIDGE.

falsework, and it was necessary to make the bridge in one span and to provide for its erection by other than usual means. Furthermore, the extreme skew, the width of the street and the omission of a truss on the center line of the street prohibited the use of top lateral bracing. The problem was solved by the late John E. Cheney, then the assistant city engineer of Boston, who designed the structure with two double pin-connected pony trusses of 216-ft. span. Each half of the double truss was in reality a complete truss; and the two parts, placed 6 ft. apart on centers, were so connected together as to constitute a structure rigid in itself, requiring no outside bracing for its support. The design was notable in being one of the longest pony-truss spans in existence. The span of 216 ft. was divided into 16 panels of 13 ft. 6 in. each; the depths of truss varied from 9 ft. 4 in. at the ends to 24 ft. at the middle, the top chord being curved and the bottom chord straight. (See Fig. 1.)

The floor beams were double plate girders tied together on the top and bottom flanges by latticing and tie plates and having the webs connected at intervals by diaphragms. The floor beams extended beyond the trusses, forming brackets for the support of the sidewalks. The connections of the floor beams to the trusses were so designed as to distribute the loads from the beams equally to the two halves of each main truss, and were made by pins passing through the beams and through small girders connecting the double posts of the trusses. The principal floor beams were nearly 80 ft. long over all and had a span between supporting pins equal to the distance apart of the main trusses, center to center, viz., 54 ft. 1 in. The depth of these principal beams back to back of angles was 3 ft. 8 in. On account of the skew, most of the floor beams were placed with one end on an abutment, some of these beams being so short as to require anchorage to the abutment masonry.

All stringers were of hard or yellow pine; the lower course of roadway planking was 3-in. hard pine; the roadway wearing surface was 2-in. spruce; and the sidewalk plank was 1½-in. hard pine.

In the trusses of the original bridge steel was used for main members for the first time in any bridge built by the city of Boston. The top chords, end posts, all eye-bars 4 in. wide and over, chord pins and rollers were made of Bessemer steel. All other parts of the trusses, the entire floor system and the bottom lateral bracing were made of wrought iron.

The requirements for the steel as determined from standard

test specimens were: Tensile strength, 62 000 lb. to 70 000 lb. per square inch; elastic limit, not less than 35 000 lb. per square inch; elongation in 8 in., not less than 22 per cent.; and reduction of area, not less than 45 per cent.; these requirements being substantially equal to those of the present day for medium steel. The specifications permitted the use of either Bessemer or open-hearth steel, and a high grade Bessemer steel was supplied by the mills of Carnegie, Phipps & Co., of Pittsburg, Pa. The steel eye-bars were manufactured by the Edge Moor Iron Company, of Wilmington, Del.

Full-sized tests of four of the steel eye-bars were made with satisfactory results, the details of the tests being given below.

Size of Bar.	5 x 1.	6 x 1.	6 x 1½.	4 x ⅞.
Length, back to back, of pin holes, feet	13.89	13.89	13.89	27.5
Elastic limit, pounds per square inch	44 390.	36 460.	36 520.	38 210.
Tensile strength, pounds per square inch	65 110.	61 870.	58 770.	62 420.
Elongation, per cent. in 12 ft. ...	18.1	19.	14.9	...
Elongation, per cent. in 26 ft. ...	...	...	...	13.
Reduction of area at fracture, per cent	46.	49.4	50.	55.

The bridge was designed to carry the following live load:

Sidewalk: 100 lb. per square foot from fence to center line of double truss.
Roadway: 80 lb. per square foot from center to center of double truss (54 ft. width), also a single 20-ton wagon.

Although the bridge was designed for a live load covering every square foot of its floor surface, including the floor surfacing at the trusses, it is to be noted that the trusses practically excluded live load from a strip 8 ft. wide at each sidewalk.

The unit stresses allowed were the following, no allowance being made for impact:

Steel: Tension on Bessemer eye-bars..............17 500 lb. per sq. in.
Compression base unit for column formula...13 333 lb. per sq. in.
Wrought Iron: Allowable tension ....12 000 lb. per sq. in.

It will be seen that great confidence was placed in the ability of the Bessemer steel eye-bars to withstand tension, the tensile unit of 17 500 lb. per square inch (without impact allowance) being considerably higher than that now commonly used for open-hearth medium steel. In steel compression members, however, the conservative practice was followed of using for the

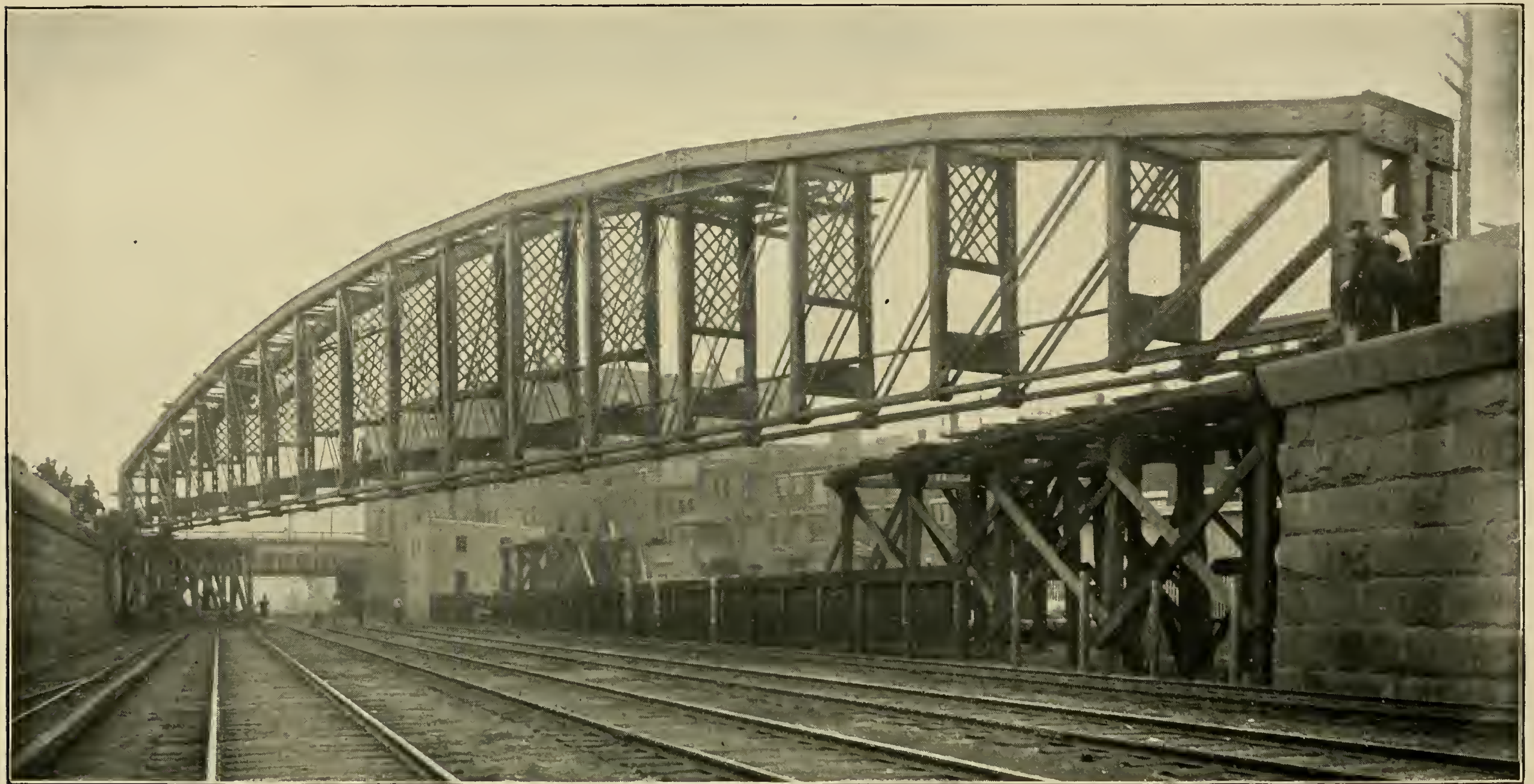


Fig. 2. Swinging Trusses of Original Bridge into Position across Tracks of Boston & Albany Railroad.

FIG. 27. GENERAL VIEW OF BRIDGE AS FINALLY RECONSTRUCTED.

base unit of the column formula a compression unit considerably less than that allowed in tension. In the top chords of the trusses the maximum actual compression unit under full load was less than 13 000 lb. per square inch.

Measured by the standards commonly accepted by engineers just prior to the Quebec Bridge accident, one would say that in the original Boylston Street trusses the top chord was considerably stronger than the tension members of the truss, although from what has been learned since the disaster of 1907 it is probable that in actual strength the top chord was not so much stronger than the eye-bars as one might have thought. However, as it was in the eye-bars that the worst corrosion of the trusses occurred, while the top chords, which had been kept well painted and nearly free from gases, were practically as good as new after nineteen years' service, the top chords then were retained and used in the reconstruction of the bridge just carried out, while the remainder of the trusses found their way to the scrap heap.

The general design and detailed drawings for the bridge were prepared by the engineering department of the city of Boston under Mr. Cheney's direction. The construction of the bridge superstructure was let to the Boston Bridge Works, the price paid under the contract being $46 490.90.

An account of the erection of the trusses of the bridge will be found in the Twenty-Second Annual Report of the City Engineer of Boston (for 1888) as follows:

"Several methods of putting the main trusses of the bridge in place, without the use of falseworks in the railroad location, were considered, but the railroad officials having consented to allow their tracks to be occupied by movable falseworks for a few hours on Sunday mornings, the contractor was enabled to carry out the plan devised and preferred by him.

"Each truss was erected on a staging at the side of, and parallel to, the railroad, one end of the truss resting on an abutment and the other end on a timber horse or tower. Between the truss shoes and the top of the tower were placed iron rollers, working between bars of railroad iron, and underneath the tower were wooden rollers resting on timber sills.

"When the truss was connected, its abutment end was placed upon an hydraulic jack and the tower end swung about this jack as a pivot to the opposite abutment, the tower moving, by means of the wooden rolls, on sills laid across the railroad tracks. (See Fig. 2.)

"When the tower had reached the abutment, the top of the tower was adjusted to the proper level by means of jacks, and the end of the truss moved on the iron rolls and railroad iron from the tower to its proper place on the abutment.

"The trusses were swung into place on the mornings of July 22 and 29, 1888, respectively, about four hours being taken each morning for doing the work, including time spent in waiting for the arrival and passage of trains on the tracks crossed."

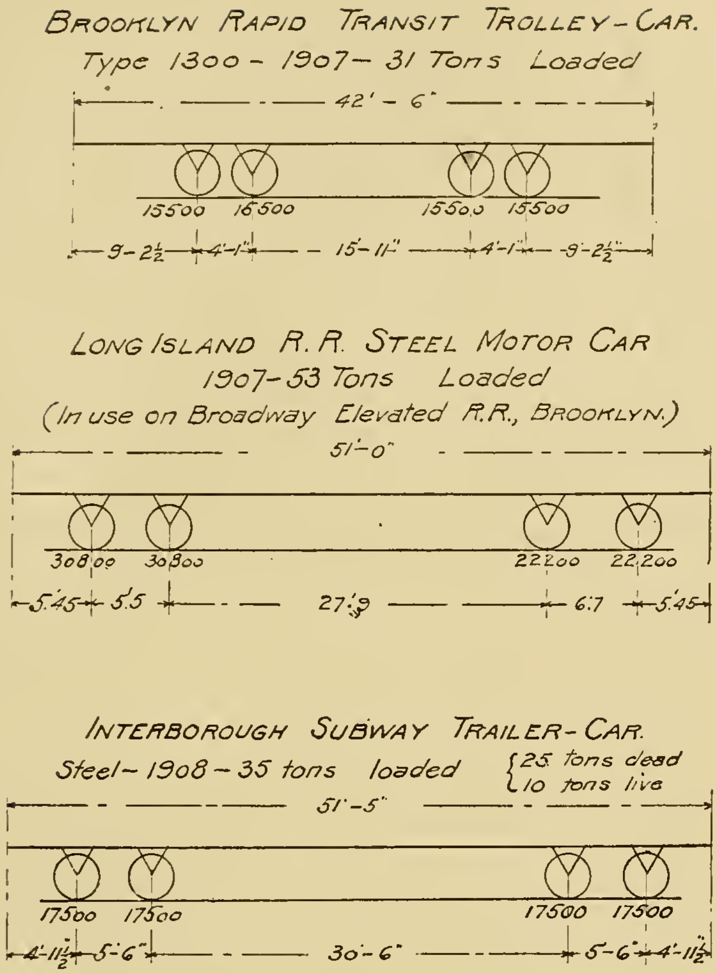
Design of the Street Railway Bridge.

By Professor Spofford.

The writer's connection with this bridge began in June, 1906, when he was engaged by the Boston Elevated Railway Company to examine and report upon certain Boston bridges across which it was desired to operate heavier cars than those previously used. The instructions originally given were to report upon the safety of these bridges under the 50-ton and 42-ton cars shown in the following diagrams, in which are included, for comparison, the weights of the heaviest cars now operated in New York City, the data for which were furnished the speaker by Mr. Henry W. Hodge, of the firm of Boller & Hodge, consulting engineers, of New York. (See Fig. 3.) Of the bridges investigated, the bridge under discussion was found to be the only one presenting a serious problem, though of the other bridges, one or two required some strengthening, and one, the Huntington Avenue Bridge across the Boston & Albany Railroad, was known to be in such a seriously corroded condition as to render it dangerous to operate heavier cars than those already in use, and impossible to permanently strengthen without entire reconstruction.

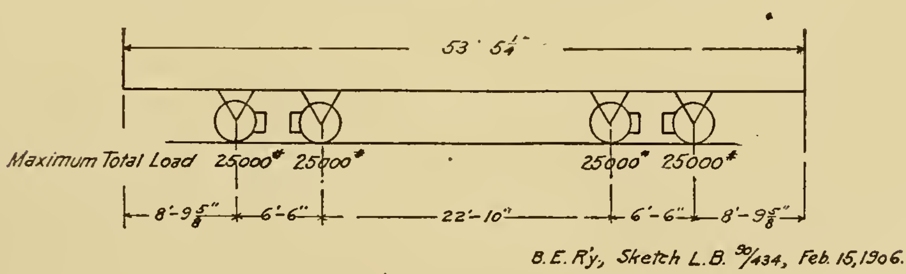
Computations quickly showed the floor system of the Boylston Street Bridge to be unsafe for the new loads, regardless of the corrosion which had occurred, and reconstruction was surely necessary. A computation of the truss stresses which the heavy cars would produce showed these to be highest in certain members of the bottom chord in which the stresses, even on the assumption that no loss from corrosion had taken place, were found to be too high for the Bessemer steel of which the bridge was built, a material treacherous at the best and long ago discarded for important structures where life and death are in the balance. A cursory examination from the ground below showed furthermore that considerable corrosion had occurred. This was anticipated as the location of the bridge between storage yards and round houses, with locomotives passing almost continually and frequently standing under the structure, seemed especially bad. A careful examination was, therefore, made by means of ladders erected on the railroad location and protected by flagmen under the direction of the section foreman. These ladders were fur-

FIG. 3.

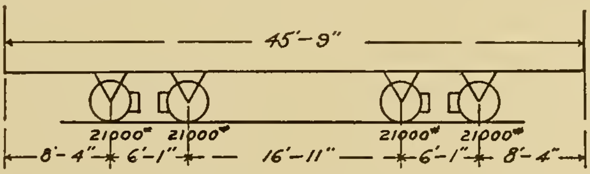


Each of the above is the heaviest car of its type in use in Greater New York in December, 1908.

50–TON BOSTON AND WORCESTER STREET RAILWAY CAR.



BOSTON ELEVATED RAILWAY CO. 42–TON TUNNEL CAR.



Weight unloaded,	63,350.	B. E. Ry. Sketch D. 3218, revised to March 22, 1907.
Maximum load,	20,800.	
Total,	84,150.	

nished and operated by one of the street railway emergency gangs, and during this examination the writer was accompanied by representatives from the city engineer's office.

The most serious corrosion discovered at this time was in the bottom flanges of the floor beams where the outstanding angle legs were seriously reduced in size, and the lattice bars used to connect the two halves of the double floor beams were in one case found to be entirely eaten away, and in other cases so reduced that they were easily broken by a single blow of a light hammer. The bottom chord eye-bars were also considerably corroded, but their thickness was considerable and the percentage of reduction was consequently not especially large, though their section was so reduced as to render it unsafe in the writer's opinion to permit unrestricted operation of the proposed new cars. In the examination, no evidence was seen of serious corrosion of the diagonals at the floor level, nor was there any suspicion in the writer's mind nor in the mind of the representatives of the city that the corrosion at that level would be materially greater than that lower down and more directly subject to the blast action from the stack, the force of which was quite evident during the examination. Moreover, these diagonals were not stressed as high as the bottom chord and in many panels had considerable excess section because of the impossibility of getting bars small enough to give just the right area. In view of the condition actually found to exist when the bridge was stripped and the bars cleaned, the writer regrets that he did not carry out his half-formed intention to strip the flooring and examine the truss from above, rather than from ladders below, which would have been less dangerous and, in the light of the facts disclosed, more satisfactory. It is the writer's belief that this serious corrosion at the floor level was due to the wooden floor proving sufficiently tight to restrain the locomotive fumes and keep almost constantly in place at that level a thin film of corrosive gases.

Because of the high stresses and deteriorated condition, it was reported to the railroad that the floor system must be reconstructed at all events, and that the trusses would need to be strengthened to permit unrestricted operation of the cars proposed, although it was suggested that the operation of the cars might be limited in such a manner as not to seriously overstrain the trusses. The restriction of traffic by requiring a certain distance to be maintained between cars did not meet the approval of the operating department of the railway, although attention

may be called to the fact that the enormously heavy surface-car traffic across the Brooklyn Bridge has been controlled in this way for years, and that the congestion of traffic on this bridge is apparently in no way due to this cause, but is brought about by terminal conditions. After considerable deliberation it was finally decided to proceed with the complete strengthening along the lines suggested by the writer, who was authorized to prepare the necessary plans. Several schemes for this strengthening appeared possible and are enumerated below.

First. The complete removal of the existing floor system and the swinging of the trusses to a position parallel to the railroad track where they could be supported by sub-falsework which could not be constructed with the bridge in position; the removal of pins, the addition of longer and, where necessary, larger diameter pins; the erection of additional eye-bars, and of other members where necessary; and, finally, the swinging of trusses into position again and construction of a new floor system.

Second. The erection of temporary trusses to sustain the old structure and the addition of new pins, bars and floor system as in the first method.

Third. The erection of a center truss, together with the changes necessary in the floor system to make the latter strong enough when supported by the center truss.

Fourth. The erection of a new truss on each side between the old trusses and connected rigidly to them, and the construction of a new floor system to carry the Elevated Railway traffic.

Fifth. The erection of new trusses as above, supported laterally, but not vertically, by the old trusses, and the construction of a new floor system to be supported by the new trusses and to carry the street railway traffic only.

Of these methods, the first two seemed unnecessarily expensive, and the first, moreover, would result in entire stoppage of traffic for a considerable time. The third would decrease the roadway clearance considerably, would require overhead bracing for lateral stiffness, which the sharp skew and limited headroom prohibited, or else new double trusses of considerable width, which would reduce the clearance too much. Such center trusses would also be heavy, as they would have to carry much more than one track load.

The fourth and fifth methods could be carried out without cutting off all traffic, would be economical of material, would make the bridge safe for the railroad traffic, regardless of the con-

dition of the old trusses, and would afford the opportunity to strengthen still further the old trusses wherever that might be necessary without additional support by falsework or otherwise.

A superficial consideration of the fourth and fifth plans would perhaps give the impression that the fifth would require more material. This is, however, incorrect as the addition of new material to an old structure without supporting the latter on falsework is uneconomical since the new material will not relieve the old of its dead stress and will carry only a portion of the live stress. The lack of economy of this method as compared with the addition of independent members is well illustrated by the following example:

Let the dead stress in a given bar	=	100 000 lb.
Let the original live stress	=	80 000 lb.
Let the original area	=	12 sq. in.

To strengthen the above bar by the addition of new material so that the unit stress under the same dead load and an additional live load of 120 000 lb. will not exceed 15 000 lb. per square inch requires the addition of 18 sq. in.* To carry this increased live stress by a new bar requires the addition of only 8 sq. in., or four ninths of the material needed for the first case.

In view of these reasons, the fifth method was adopted and plans made accordingly. As in all repair work, numerous difficulties were encountered, most of which were anticipated from the start. Among the more important of these may be mentioned the following:

The design of the intermediate posts of the new trusses to permit their erection between the old trusses without interference with either the transverse vertical bracing shown in Fig. 5, or the double floor beams of the old structure; the support of the new trusses laterally by means of the old structure without restricting the free vertical and longitudinal movement of either truss; the erection of the new floor system without shutting car travel from more than one track at a time, and without interfering with existing floor beams and lower laterals; the separation of the floor of the new bridge from that of the old so that both might deflect freely and at the same time have a continuous surface.

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* This may be determined by the solution of the following equation in which A = new material required.

$$15\,000 = \frac{100\,000}{12} + \frac{200\,000}{12 + A}.$$

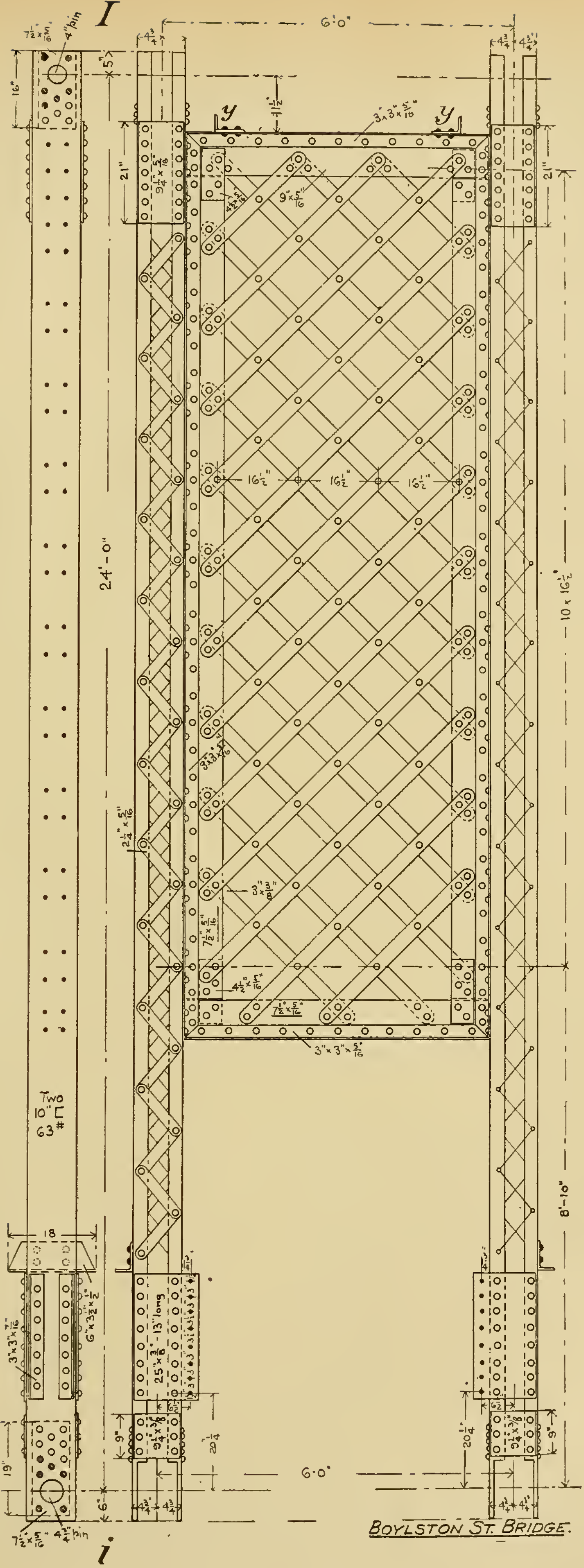


FIG. 5. VERTICAL TRANSVERSE BRACING BETWEEN ORIGINAL TRUSSES.

Fig. 4 shows the relation between the new and old work. Fig. 6 indicates the method adopted in solving the first of the above-mentioned problems. The intermediate posts were made in upper and lower sections, each of which was in halves, each half

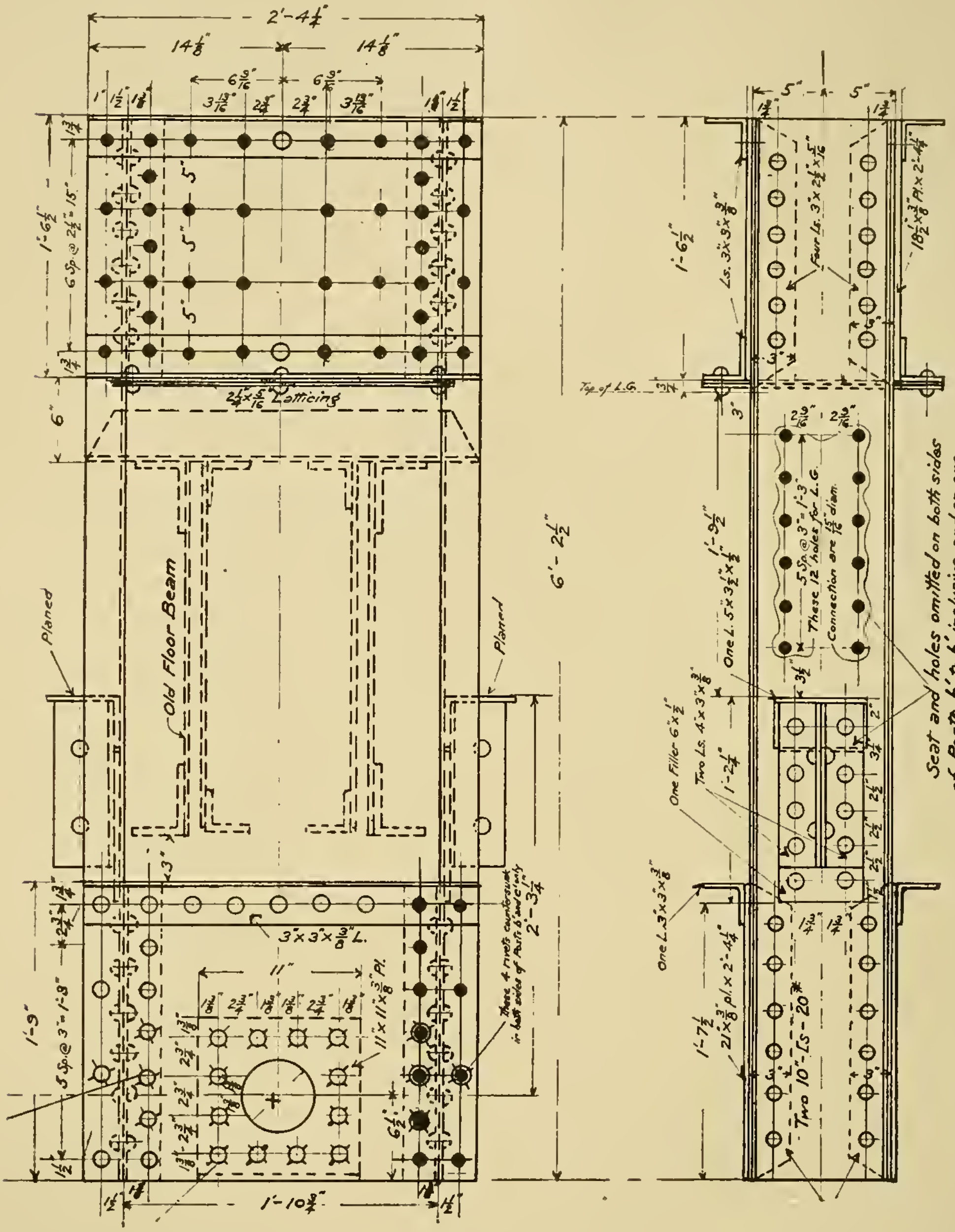


FIG. 6. RAILWAY TRUSSES. BOTTOM HALF OF AN INTERMEDIATE VERTICAL UPPER HALF TO BE RIVETED TO THIS HALF IN FIELD.

being made of sufficient strength to carry one half the load as an independent column. In this way the upper sections were made to straddle the transverse bracing shown in Fig. 5, and the lower sections the old floor beams shown dotted in Fig. 6. The division

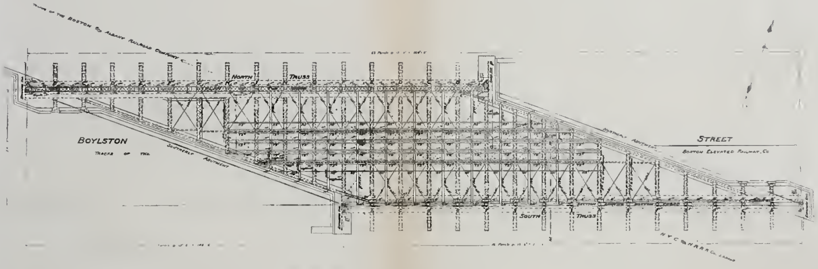


Fig. 4. General Plan showing Relation between Original Structure and Railway Structure.

New material shown by full lines.
Old material shown by dotted lines.

of the posts into upper and lower sections was made necessary by the inability to drive splice rivets and pins in the upper chord when the latter was in position between the chords of the old structure. The upper chord, the upper post section and the upper portions of the diagonals, which were all adjustable, were, therefore, erected with the top chord supported on the transverse bracing between upper chords of the original trusses. After the upper half of the truss was thus assembled this bracing was removed, temporary bracing provided in another position and the whole upper section lowered until it could be connected with the lower portion which had previously been put into place.

The method of supporting the new truss laterally is indicated by Fig. 7. The horizontal ribs of the top chord struts shown in the figure were passed through holes cut in the top chord ribs and of sufficient size to permit free vertical deflection. The vertical ribs were then riveted to these horizontal ribs, and the ends of the strut thus formed riveted to the old trusses. The center portion was made so that it would be a close fit transversely in the new top chord, but free to hold it vertically. The lateral bracing previously removed from the plane of the top chords of the old structure was then replaced, but was moved longitudinally so that the diagonals would clear the pins of the new chord. In order to put this bracing into place it was necessary to cut holes in the new top chord as shown in Fig. 7. The bottom of the new truss was also supported laterally by means of guide angles riveted at both ends to the top flanges of the old floor beams. These are shown in Fig. 6.

Interference between the new and old floor beams was prevented by locating the new beams midway between the old beams and consequently midway between panel points of the new trusses. Support for these floor beams was provided by longitudinal girders extending from panel point to panel point and lying in the plane of the new truss. These longitudinal girders were riveted at one end to the truss post, but the other end was bolted and the nuts were not screwed tight, the reaction being carried by a bracket. This arrangement was made in order that the longitudinal might not prevent free action of the truss. The floor beams were made in halves to permit erection without interference with travel on more than one track at a time and were spliced in the field at a point slightly removed from the center.

The method of procedure given in following plan of erection indicates clearly the unusual character of the construction and the difficulties to be overcome.

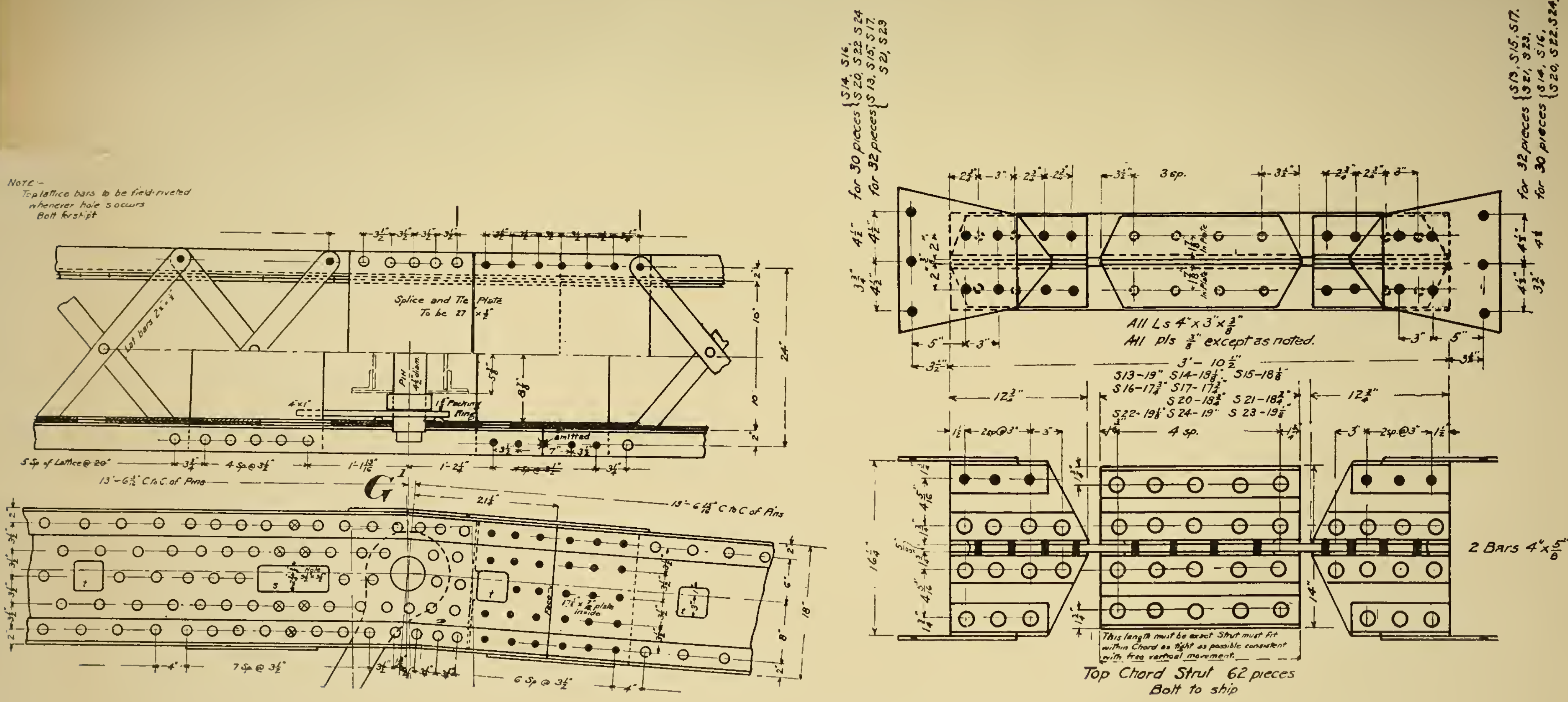


FIG. 7. RAILWAY TRUSSES. PORTION OF TOP CHORD AND TOP CHORD STRUTS.

Proposed Plan of Erection.

The new work shown by piece marks on this sheet and in detail on sheets 2–13, inclusive, dated October 30, 1906, has been designed in accordance with the following method of erection:

1. Close to traffic southerly sidewalk and roadway up to southerly car track.

2. Remove sufficient sheathing on southerly side of bridge to permit the removal and reconstruction of the existing bottom struts S^1, S^4 and S^5, shown on sheet No. 1 of original set of drawings dated January, 1888, and the erection of the bottom sections of the intermediate posts and diagonals, the end posts and shoes, the bottom chord and the longitudinal girders.

3. Cut out the struts S^1, S^4 and S^5, mentioned above, with the attached laterals, and reconstruct struts as shown on sheet No. 2 of 1906 set of drawings. Reconstruct also easterly end of abutment strut S. These struts and rods are to be removed from not more than two panels at once. Drill new rivet holes in existing floor beams for connection of these struts, replace struts in new position and add new laterals. Notch flanges of old floor beams where necessary to clear diagonals of new truss; drill also new holes in top flange of all existing floor beams to fit guide angles shown on sheet No. 2 of 1906 set of drawings.

4. Put into place at each panel point, while both adjoining struts are disconnected, the bottom section of the intermediate post, which is made in halves to facilitate erection, and should be riveted together at bottom before struts are riveted in new position, as otherwise it will be impossible to drive certain of the rivets. The bottom chord pin should be put into position before the two sections of the post are assembled, as it cannot be put in after the post section is in its final position. After assembling these sections of the bottom posts they should be temporarily supported on the existing floor beams, but should not be riveted at top until after the entire truss is assembled.

5. Put into position the longitudinal girders and bolt to posts, but do not rivet.

6. Assemble the bottom chord bars and bottom sections of intermediate diagonals. Note that these must be slipped over the ends of the pins, as pins will already be in place.

7. Remove bracing between top chords, replacing it by temporary bracing satisfactory to the city engineer.

8. Assemble top chord, end posts, end diagonals, top lateral bracing and top sections of intermediate posts and

diagonals. These are to be assembled at a height greater than final elevation, in order to permit the driving of splice rivets and pins, and are to be supported by blocking carried by the sway bracing between the existing trusses. Note that the intermediate posts are made in halves to facilitate erection.

9. After upper portion of southerly truss is completely assembled, remove end sidewalk brackets and lower the truss into its final position, support the end posts on blocking, bolt the intermediate posts together at splices and connect the bottom of the end diagonals to chord pin.

10. Rivet verticals at splices, connect adjustable diagonals and chords and rivet longitudinal girders at one end, bolting at other. Nuts on bolts are not to be screwed tight, as it is desirable to provide for $\frac{1}{8}$ in. play in girders. After nuts are on, hammer bolt threads sufficiently to prevent nuts working loose.

11. After truss is finally assembled, riveted and adjusted, jack up slightly at ends, remove temporary supports of post sections at floor beams, put into place rollers and fixed end bearings, lower truss into final position, rivet and adjust top bracing and rivet end portal plates and sidewalk brackets.

12. Strip remainder of sheathing on southerly roadway and car track and put southerly halves of floor beams into place temporarily, removing bottom bracing in one panel at a time. These floor beam sections may be temporarily supported at northerly end by fastening to existing floor beams. Reinforce also at this time the old floor beams, F^5 and F^6, at easterly end of bridge, and make whatever other slight changes are necessary in southerly halves of other floor beams.

13. Lay new permanent sheathing on southerly roadway and sidewalk; lay also temporary track stringers on southerly car track, supporting stringers in both cases on old floor beams, and using old stringers under car track and under roadway, where permitted by the city engineer.

14. In a similar manner erect northerly truss and floor beams, but in this case rivet floor beam sections together at splice before relaying sheathing and put into place the permanent track stringers in northerly track. Note that some of the splice rivets in top flange of F^{14} cannot be driven at this time, but must be driven when temporary southerly track is removed. All other splice rivets should, however, be driven.

15. Finally replace temporary track on southerly side.

The floor construction is shown in Fig. 8. The design of this to fulfill the conditions previously mentioned was somewhat

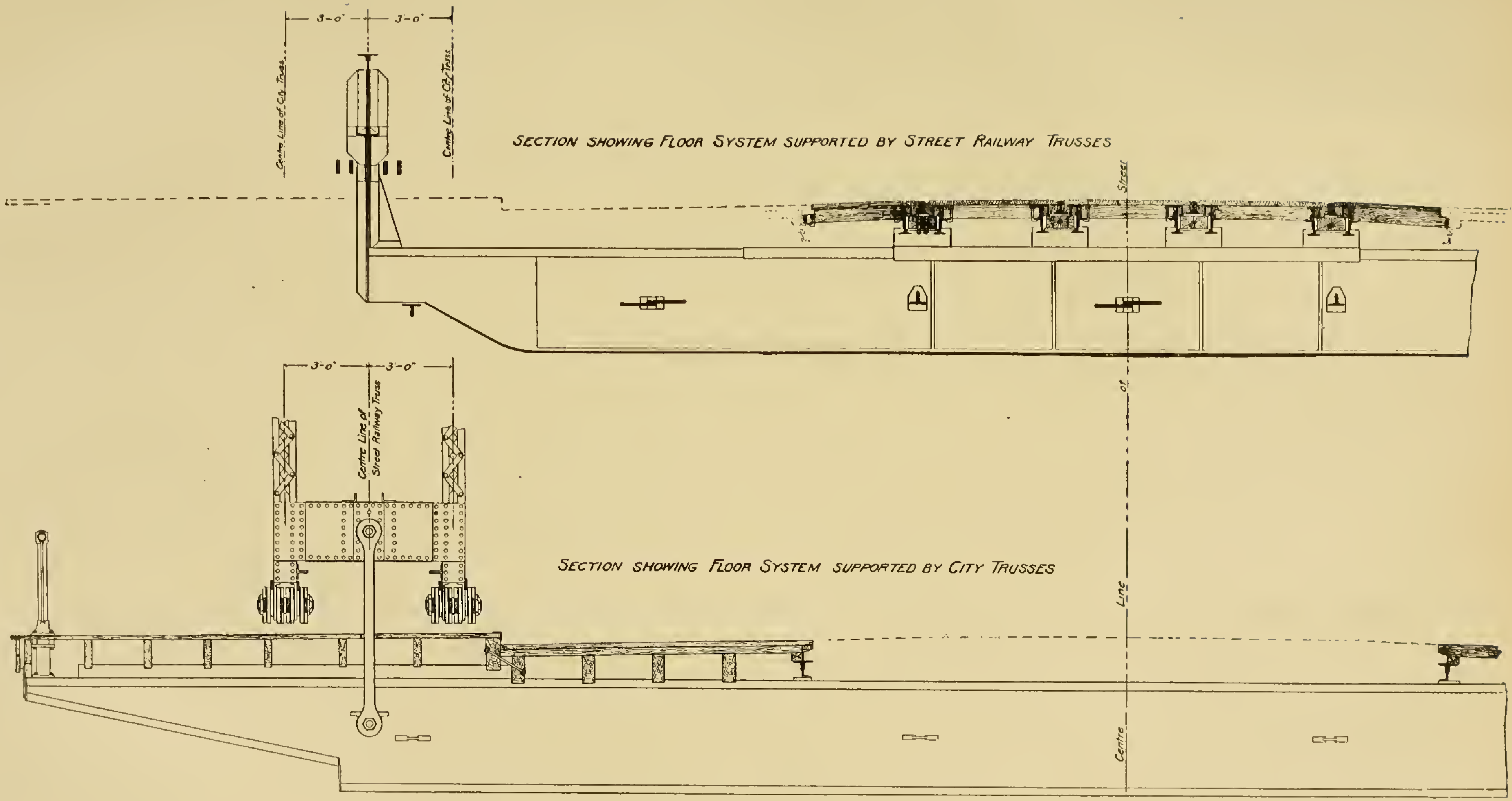


FIG. 8. CROSS SECTIONS OF BRIDGE FLOOR AS FINALLY REBUILT.

of a problem because of the very limited headroom. To prevent interference between the trusses it was necessary that the old stringers should clear the new floor beams, and the stringers of the new structure clear the old floor beams. It was also necessary to have a strip of flooring on either half of the bridge which should act like a hinge. To accomplish these results the new stringers were each made of two I-beams connected at the bottom at close intervals by $\frac{3}{4}$-in. plates, which, in turn, support hard pine rail seats of a height such that the top of rail is level with the floor surface. These stringers are supported on brackets placed on top of new floor beams and are stiffened by diaphragms placed at 4-ft. intervals. The floor timbers are supported on shelf angles riveted to the sides of the stringers. In order to construct the floor hinges mentioned the wooden roadway stringers of the old structure adjoining the rail stringers were replaced by channels and the section of the floor between these roadway stringers and the track stringers supported on shelf angles and bolted by hook bolts. The floor sheathing on these sections is laid lengthwise, and a little clearance left at the track stringers so that there will be no interference with the hinge action. This clearance is made as small as possible to prevent the accumulation of pebbles and dirt in the crack. In order that the floor timbers might be put into place the ends of these timbers were beveled and sufficient clearance provided between them to permit the insertion of the end timber in a panel when the others were bunched together.

This completes the description of the plans adopted for the strengthening of the bridge for the additional railway loads. The execution of these plans and the appearance of the finished work is illustrated in the views which accompany the papers by Messrs. Fay and Moses.

Erection of the Street Railway Bridge in 1907 and Corrosion of the Original Bridge Then Disclosed.

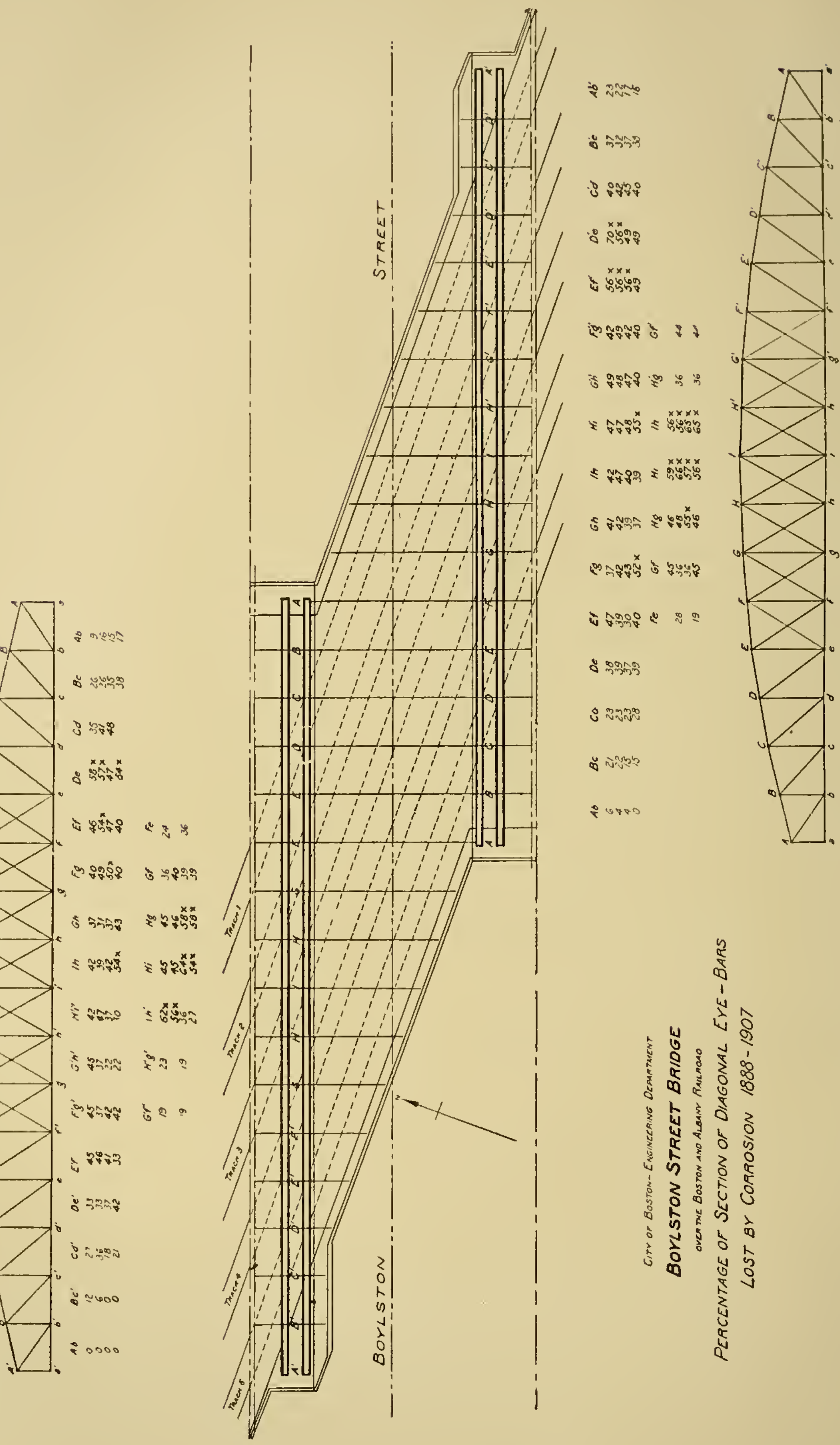
By Mr. Fay.

When the southerly half of the bridge was stripped, in October, 1907, preparatory to the erection of the street railway structure, the old metal work was cleaned of scale and rust and its condition was found to be much worse than had been expected from an examination made in the summer of 1906, and showed in a striking way that the usual examination of such a bridge from below, which means climbing a ladder between the passages of trains, looking at a few selected places in the dark and clean-

ing off rust scales on those parts as best as one can under the circumstances, is by no means real inspection and cannot be relied upon to determine the true condition of a bridge in which corrosion is well under way.

The worst effects of corrosion were generally found at the easterly end of the bridge, over and near track No. 1, which is the outward bound express track of the Boston & Albany Railroad. This track is used also by switch engines in making up trains in the railroad yard just east of the bridge. The total train movements beneath the structure are between five hundred and six hundred on each week day, and about eighty on Sunday; and frequently the switch engines will stop underneath the bridge, discharging steam and smoke, which hang for a considerable time just under the bridge floor.

The floor beams at the east end of the bridge were the parts found to be in the most dangerous condition. Although built before the days of modern street cars, and, as before stated, designed only for a uniform load of 80 lb. per square foot, and a single 20-ton wagon, these floor beams were called upon to support two car tracks, each carrying cars up to 26 tons in weight, in addition to the usual and frequent highway traffic at each side of the roadway. If these wrought-iron beams had been as good as new they would have been subjected, under this loading, to unit stresses of about 15 000 lb. to 16 000 lb. per square inch in tension, no allowance being made for impact. As a matter of fact, the beams in the worst condition had corroded to such an extent that their webs, originally $\frac{3}{8}$-in. thick, were reduced to $\frac{3}{16}$ in., the outstanding legs of their flange angles were reduced from an original thickness of $\frac{1}{2}$ in. to about $\frac{1}{8}$ in., and the lattice bars connecting the flanges of the two halves of these doubled webbed beams were either entirely eaten off or were so thin that they could be broken by blows of a light hammer. The condition of one of these beams is shown in the accompanying view. (Fig. 9.) The wooden stringers rested upon the top flanges of the beams and in this case, as well as in a number of others, the outstanding legs of the top flange angles were broken entirely off at the track stringers as a result of the pounding administered by the heavy street cars. The broken flanges are not the worst feature, however, for a part of the vertical leg of the flange angle and, in the longer beams, what was left of one or two vertical bars on the inside of the web, still remained to act as flange section; and the notching of the stringers upon the beam doubtless served to give some lateral support to the top flange to make



City of Boston — Engineering Department
Boylston Street Bridge
over the Boston and Albany Railroad
Percentage of Section of Diagonal Eye-Bars
Lost by Corrosion 1888-1907
Boylston
Street
Track 1
Track 2
Track 3
Track 4
Track 5

FIG. 10.

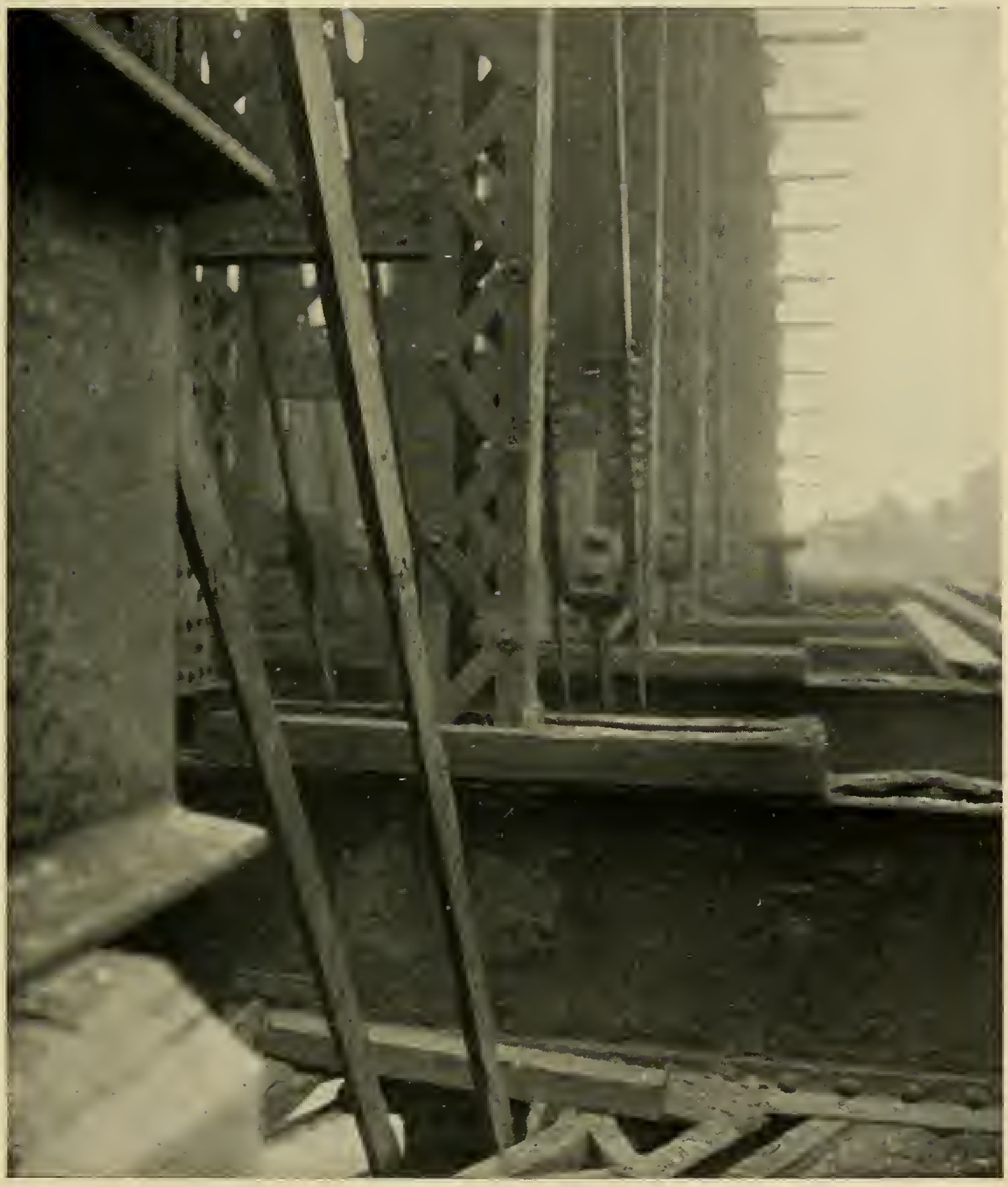


FIG. 11. TYPICAL CORRODED DIAGONAL OF ORIGINAL TRUSSES.

Fig. 9. Floor Beam of Original Bridge, Corroded and Broken.

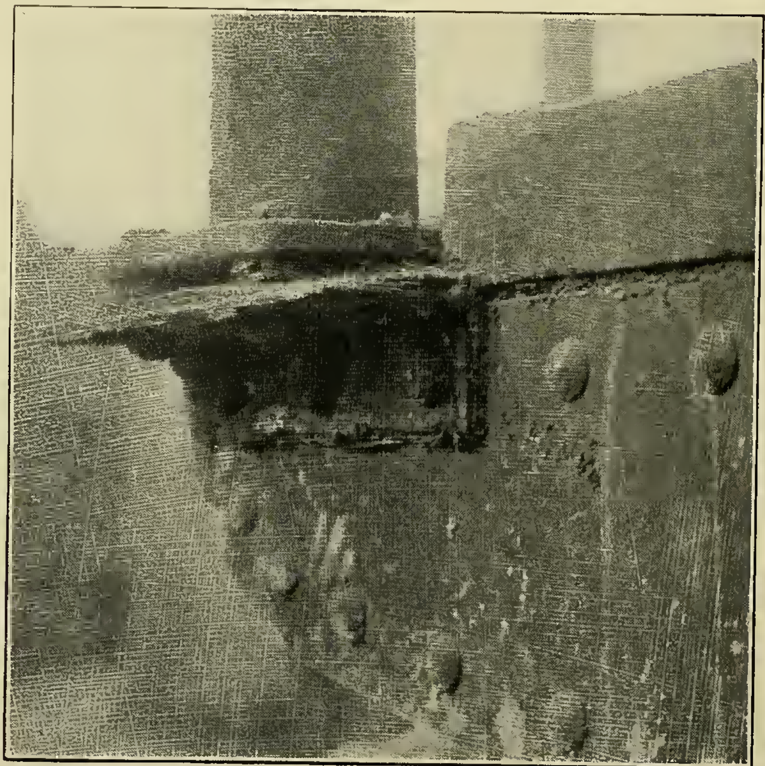


Fig. 12. Relative Corrosion of Cast and Wrought Iron.

up for the loss of the latticing. It will be noted that the floor beam was a double webbed beam and upon every other one of the stringers met in a butt joint, in which case the stringer reaction had to be carried entirely by one half of the beam, dependence being placed upon four plate and angle diaphragms to transmit the proper portion of the load to the other half of the beam. The diaphragms were made of $\frac{5}{16}$-in. plate, and, like the rest of the member, were badly rusted. In the view shown, the diaphragm plate was so far gone that a diaphragm nearest the tracks was cracked entirely through, owing to the heavy car traffic. In such a case, one half of the floor beam had to carry the whole of a stringer reaction except for that part of the load which might be carried to the adjacent stringer by the street car rail.

In the trusses, the easterly portion naturally showed the greater corrosion. The bottom chord bars were some distance below the flooring and were less subject to corrosion from locomotive fumes, although they showed the effect of blast action from the locomotives. These bars in most cases were corroded less than $\frac{1}{8}$ in. on each exposed surface, and as they were originally thicker than the diagonals, the percentage of metal lost in the chord bars was, on the whole, considerably less than that of the diagonal bars. The locomotive fumes would rise to the under side of the floor planking and the stringers would keep the gases pocketed there and would prevent them from being blown away; consequently the worst condition of corrosion of the trusses was found in the web members just beneath the planking. Here, in a large number of cases, from $\frac{1}{8}$ in. to $\frac{3}{16}$ in. of metal had been eaten away from each exposed surface. Post channels, whose webs were originally nearly $\frac{7}{16}$ in. in thickness, had been rusted until the webs were not more than $\frac{1}{8}$ in. thick, and their tie plates and latticing were badly rusted also. Many eye-bars having an original thickness of $\frac{3}{4}$ in. were found with minimum thicknesses of $\frac{7}{16}$ in., $\frac{3}{8}$ in. and even less, and as their edges as well as their sides were corroded, the loss of section in a number of the diagonals was as high as 50 per cent. to 60 per cent., reaching in one case a loss of 70 per cent. Fig. 10 is a diagram showing the extent of corrosion in the several eye-bars of the old trusses. Fig. 11 shows typical corroded diagonals.

An instance where wrought iron corroded vastly more than cast iron under precisely the same exposure appears in the accompanying photograph (Fig. 12) of the base of a railing post supported on the end of a sidewalk bracket. The post base is of

cast iron; the shelf angle on which it rests and the bolts are wrought iron. Both were just beneath the sidewalk floor, where, as just described, the corrosion was worst. If anything, the casting was less favorably situated, being directly under the planking and where the gases hung longest. Little is left of the shelf angle but laminæ of rust; the casting shows a rusty surface but is in excellent condition and was put back for another twenty years in the new bridge.

The condition of the city bridge was such that it was deemed unsafe for further traffic, and extensive reconstruction was at once determined upon as an imperative necessity.

In connection with the destruction of the original Boylston Street Bridge, it should be noted that the amount of headroom beneath such a bridge has an important influence upon corrosion. At this bridge, as is the case of many of our city bridges over railroads, the headroom from top of rail to the clearance line of the bridge was only about 15 ft., and with such low headroom the corrosive action of locomotive fumes has generally been comparatively rapid. On the other hand, at many bridges where the headroom is 18 ft., the effect of the gases under substantially similar conditions of time and railroad traffic has generally been less marked.

The contract for building the street railway bridge had been let to the Boston Bridge Works, which concern had built the original bridge in 1888. The erection of the street railway structure was begun September 30, 1907, in accordance with a scheme of erection proposed by Professor Spofford, travel being maintained upon both sidewalks, upon the northerly car track and the northerly half of the roadway. The old southerly trusses had to support the southerly street railway truss until the latter was fully assembled and swung. Although there was some decrease in the dead weight of the floor, and the live load on the old southerly trusses was limited to an amount considerably less than that which had been previously using the bridge, the contractor was unwilling to assume the risk of placing the dead weight of the new truss upon the old trusses until some of the worst corroded diagonals of the latter had been strengthened.

A reinforcement was used consisting of a U-shaped bar bolted to the diagonals above the point of corrosion, combined with another U-shaped bar around the bottom pin, the latter bar being adjustable and connected to the first by a casting.

After the erection was well under way the contractor asked permission to close the whole roadway to travel in order to work

on both trusses and the entire floor system at one time, claiming to be able to materially hasten the completion of the work if this were done. This permission was granted by the city and by the Boston Elevated Railway Company, and the entire bridge, except the two sidewalks, was closed to travel October 25, 1907. The erection of the street railway bridge was carried on to a point where the trusses, all of the new floor beams and the new bracing were completed. The Boston Elevated Railway Company desired to resume street car traffic across the bridge at the earliest possible moment and to put into service cars weighing 42 tons, and as it would have taken some time to get an appropriation from the city for rebuilding the original structure, and still further time before the work of rebuilding could have been begun in the field, the scheme of putting on a permanent floor was abandoned and the Boston Elevated Railway Company proceeded to lay temporary tracks. As the old city floor beams were insufficient to carry these tracks near the abutments, a temporary construction of I-beams was put in at each end of the bridge. This construction consisted of a pair of 20-in., 65 lb. I-beams placed longitudinally upon the old floor beams near the trusses; and to these longitudinal beams were hung I-beams which served as temporary floor beams for the support of the track stringers, the opposite ends of these temporary floor beams being supported upon blocking at the abutment.

The temporary track construction consisted of track stringers and supplementary stringers of wood upon which was laid a 3-in. plank floor about 20 ft. wide for the length of the bridge, a substantial fence being provided at each side of this flooring. On top of this planking T-rails were laid at an elevation considerably above that of the rails in the former bridge, the rails being above the tops of the parapet stones. No attempt was made to provide for team travel by laying flooring up to the top of the rails.

The street railway structure was completed and the temporary track was opened to travel on November 20, 1907, and during the whole work travel had been maintained upon both sidewalks. From November 20, 1907, until the work of rebuilding the city structure was begun in July, 1908, foot travel was continued on both sidewalks and all of the car travel of Boylston Street crossed the bridge on the temporary tracks, but no team travel was allowed and the Elevated Railway Company maintained a flagman at all times to prevent teams from attempting to cross the temporary floor.

In anticipation of the closing of the bridge to all travel during the work of reconstruction by the city, the Boston Elevated Railway Company secured a location, and in June, 1908, laid temporary tracks from Boylston Street to Massachusetts Avenue through Hereford and Newbury streets. All car travel was diverted to this temporary route soon after July 1, 1908, just before the rebuilding of the old city bridge was begun.

Care of the Original Bridge.

By Mr. Fay.

Before leaving the subject of the original Boylston Street Bridge to take up that of its reconstruction, it may be well to pause for a moment in our description to answer some questions that may arise as to the care and condition of the old bridge during its nineteen years' life. Was the bridge kept properly painted? Why did corrosion take place to such an alarming extent? Why was not its true condition known before the building of the street railway bridge was begun? To answer these and similar questions, a general statement regarding the maintenance of bridges by this city may be illuminating.

The responsibility for the maintenance of the city bridges in Boston lay for many years, and rests at present, with the superintendent of streets, his duties being delegated to a deputy superintendent of bridges, who is the officer in charge of the bridge division of the street department. Prior to 1891, and during the years 1906 and 1907, the bridge division was classed as a separate department whose superintendent was appointed by the mayor. All expenditures for maintenance are met from appropriations for the bridge division. The city engineer is required by ordinance to report annually upon the condition of the bridges and to supervise all repairs affecting the safety of the structures. Annual inspection of all bridges is made by the engineering department so far as conditions will allow, more frequent inspection being made whenever the city engineer deems such inspection necessary. The city engineer, however, has not had power to enforce his recommendations and generally they have been ignored.

This arrangement has not worked well in practice, and for years our city bridges have been suffering for want of proper care. Maintenance meant the renewal of the floor surfacing and the painting of such metal work as is easily accessible and seen by the public. The more important and less accessible metal work, that below the bridge floor, has been constantly neglected,

dirt has been allowed to accumulate wherever it could find a lodging place, and only at infrequent intervals has any pretense been made of cleaning this metal work of dirt, scale and rust, and repainting it. Indeed, it is not stating the case too strongly to say that the maintenance of the bridges as a whole has been grossly inadequate, proper inspection has not been possible under existing conditions, and many bridges, particularly those over railroads, have deteriorated to such an extent that to-day they may be almost unsafe for public travel.

Boylston Street Bridge reached the danger line in nineteen years' service; Massachusetts Avenue Bridge over the Boston & Albany Railroad has just been rebuilt; Huntington Avenue Bridge over the same railroad has reached such a bad condition that an appropriation for rebuilding it has already been made; while other bridges over railroads will have to be repaired or renewed in the near future or else closed as unsafe for public travel.

Boylston Street Bridge may be cited as a typical case because in this structure the consequences of neglect have been made manifest. The speaker does not mean to imply that neglect was primarily responsible for the destruction of this bridge. Unquestionably, the chief cause was to be found in the constant presence of locomotive fumes which formed a powerful mordant and steadily attacked the metal, and the next important factor was the presence of heavy street cars, which pounded the floor beams to pieces after the gases had done most of their deadly work. Nevertheless, it is probable that if the city engineer's recommendations had been followed and the metal work had been kept properly cleaned and painted, the life of the trusses at least, if not the whole bridge, would have been prolonged for a number of years.

As for the inspection of such a bridge in which corrosion is well under way, it is found to be practically impossible to make a thorough, reliable examination of the structure from below. With trains passing at frequent intervals, even on Sunday, with the difficulty of cleaning off scale and rust under the existing conditions, and with the generally poor condition as to light, such inspection must, at best, be very superficial and places of most vital importance are often wholly inaccessible. Public safety as well as economy demands that in the case of bridges over railroads in which there is unprotected metal work beneath the floor, the entire flooring should be removed at frequent intervals and all such metal work thoroughly cleaned, examined and painted.

Rebuilding of the City Bridge.

By Mr. Fay.

After a delay of nearly six months, the city government of Boston appropriated, on April 2, 1908, the sum of $60 000 for the rebuilding of the city's bridge. Meantime, plans for the work had been prepared by the engineering department, and bids had been called for, to be received on April 3. On that date the contract for rebuilding was let to the Boston Bridge Works, Incorporated, the lowest bidder, for the sum of $52 800. The work of rebuilding provided for raising all trusses so that they should be well above the floor and should thereby be protected in the future from further destruction by locomotive fumes. The top chords of the old trusses, which were in good condition, were to be retained, but the posts, diagonals and bottom chords were to be entirely renewed. The floor beams of the street railway bridge were to be hung to their longitudinal girders by riveted hangers, while the new floor beams for the city structure were to be hung by eye-bar hangers. (See Fig. 8.) The metal work for the city structure below the floor was to be protected, so far as possible, by concrete, although it was found impracticable to so protect the eye-bar hangers and the bottom lateral bracing. Provision has been made for the easy renewal of these latter members when necessary. The new city floor beams are plate girders 3 ft. 11 in. deep back to back of angles, their ends being cantilevered to form brackets for the support of the sidewalks. Upon the top and bottom flanges of these beams are placed channels solely for the protection of the metal work of the beam, no dependence whatever being placed upon these channels as carrying stress. (See Fig. 13.) These channels are 12 in. wide and have a web ½ in. thick. On the bottom flange the channels are riveted by countersunk rivets. As the bottom channels have to resist only the blast of the locomotives, it is thought that they will last for a great many years, perhaps for the whole life of the present structure. The top channels, on the other hand, are in a position where they will be subjected to locomotive fumes as well as to moisture which will work through the wooden flooring; these top flanges carry the wooden stringers of the bridge, which fact will hasten their destruction. Consequently, the top channels are not riveted to the floor beams, but are attached to the top flanges by brass bolts in such manner that they may readily be replaced by new channels when necessary.

The photographs shown in Figs. 14 to 16 illustrate the con-

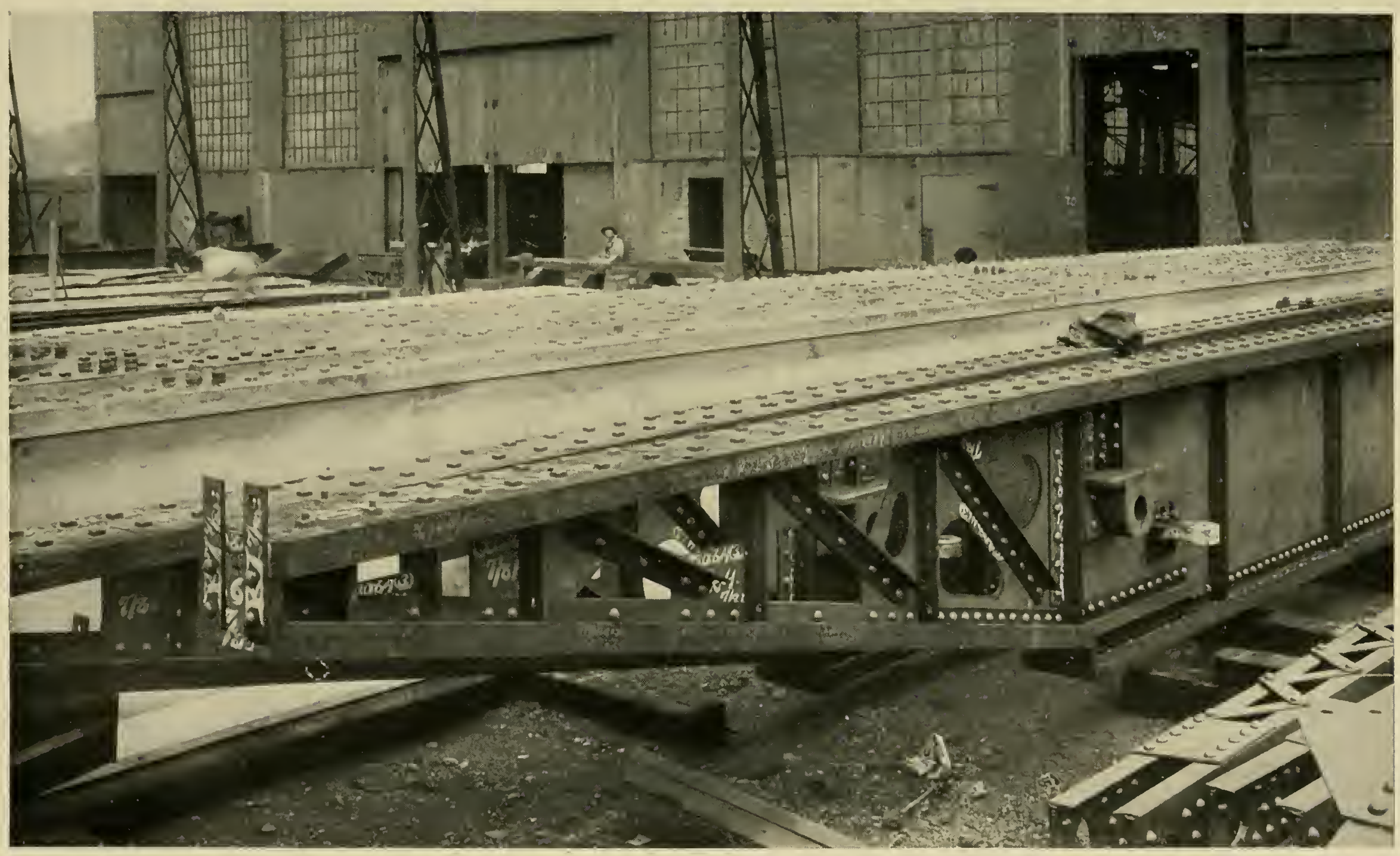


FIG. 14. BRACKET END OF TYPICAL FLOOR BEAM OF NEW CITY BRIDGE, BEFORE CONCRETING.

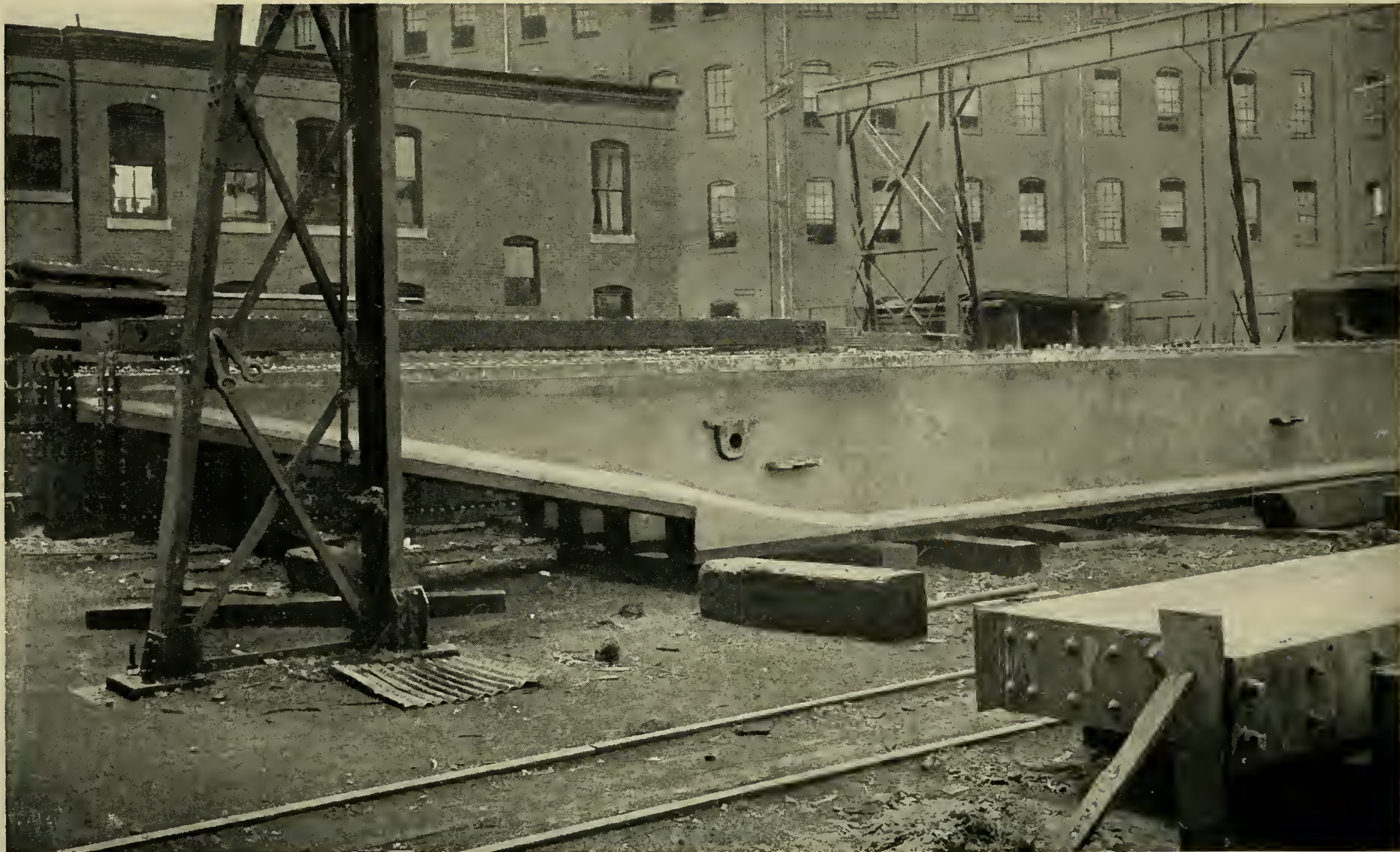


Fig. 16. New City Floor Beam with Concrete Protection Completed.

FIG. 24. ERECTION OF NEW CITY FLOOR BEAMS.

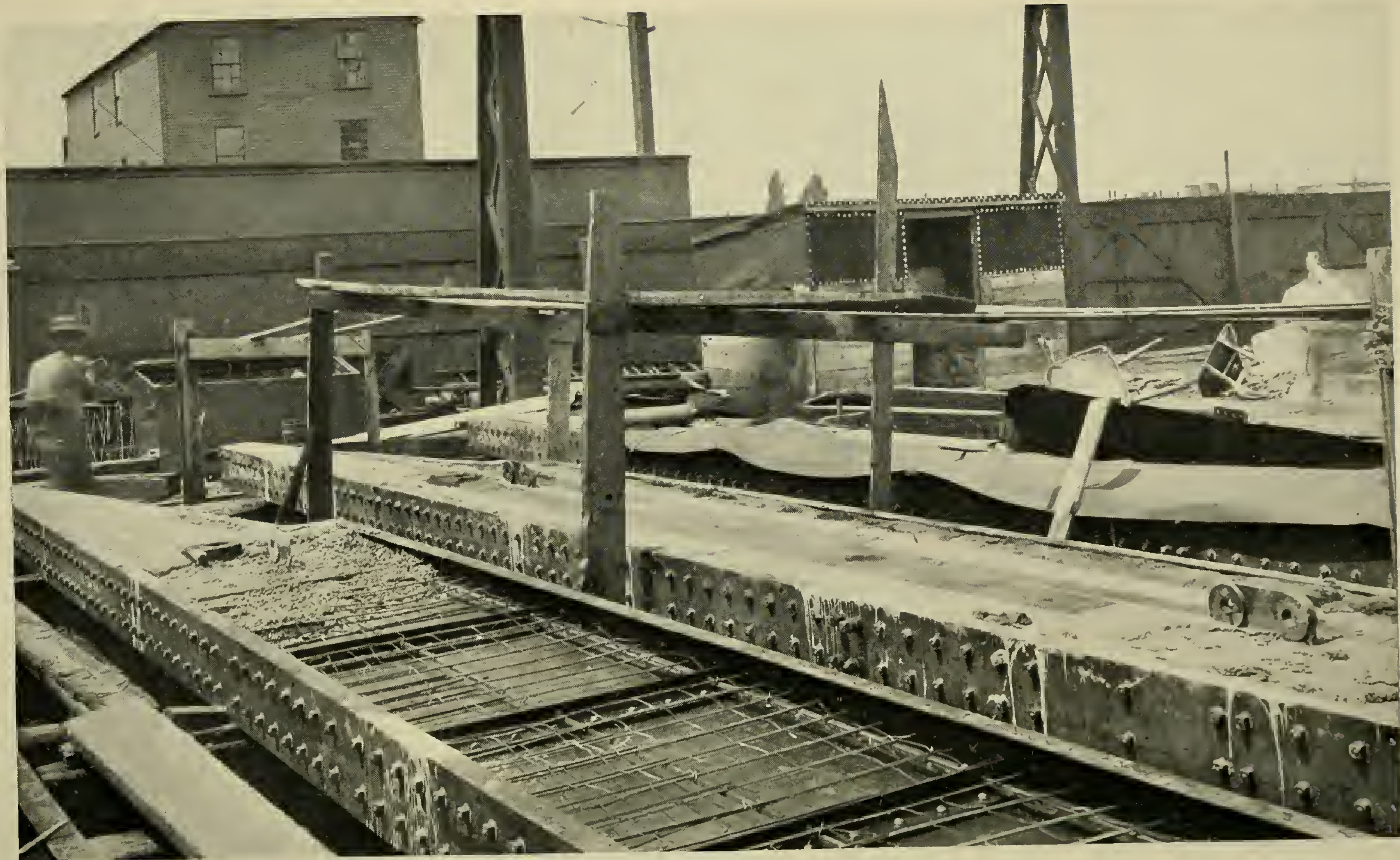
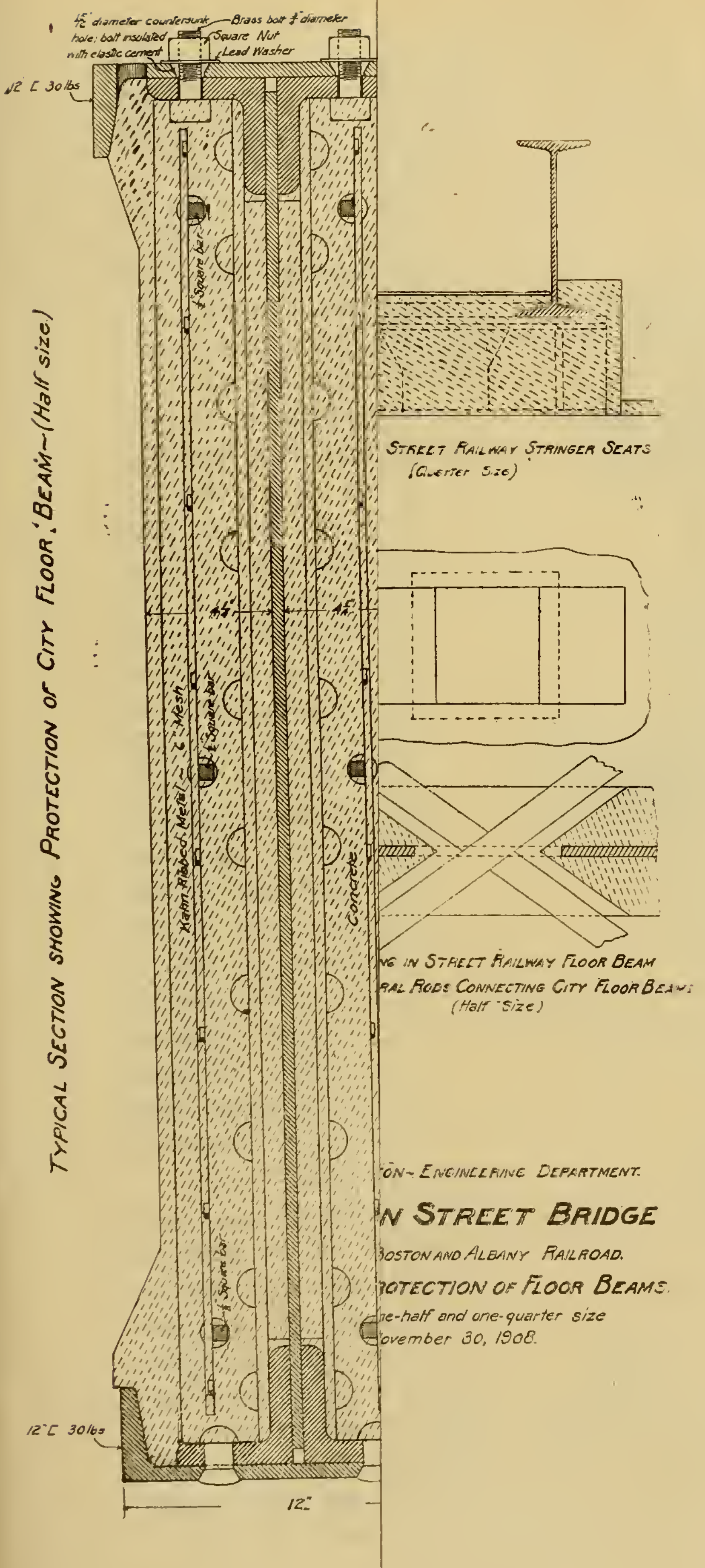
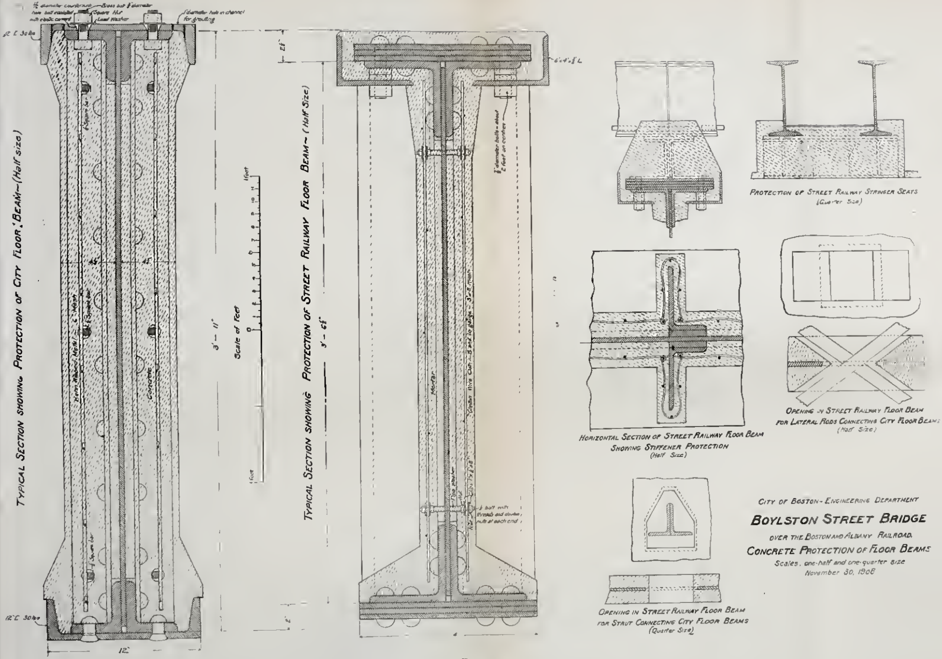


Fig. 15. Placing Concrete Protection on Webs of New City Floor Beams.



1/2" diameter countersunk hole; bolt insulated with elastic cement
Brass bolt 3/4" diameter
Square Nut
Lead Washer
12" [30 lbs
Square bar
Kahn Ribbed Metal - 2" Mesh
Concrete
12" [30 lbs
12"
Typical Section showing Protection of City Floor 'Beam'-(Half size)
Street Railway Stringer Seats
(Quarter Size)
ng in Street Railway Floor Beam
ral Rods Connecting City Floor Beams
(Half Size)
on - Engineering Department.
n Street Bridge
Boston and Albany Railroad.
rotection of Floor Beams.
ne-half and one-quarter size
ovember 30, 1908.



Typical Section showing Protection of City Floor Beam ~ (Half size)
Typical Section showing Protection of Street Railway Floor Beam ~ (Half Size)
Scale of Feet
3' - 11"
3' - 6½"
12"
Protection of Street Railway Stringer Seats
(Quarter Size)
Horizontal Section of Street Railway Floor Beam
Showing Stiffener Protection
(Half Size)
Opening in Street Railway Floor Beam
for Lateral Rods Connecting City Floor Beams
(Half Size)
Opening in Street Railway Floor Beam
for Strut Connecting City Floor Beams
(Quarter Size)
City of Boston - Engineering Department
Boylston Street Bridge
over the Boston and Albany Railroad
Concrete Protection of Floor Beams
Scales, one-half and one-quarter size
November 30, 1908

Fig. 13.

crete protection of the floor beams, while the same was being put in place at the yard of the Boston Bridge Works. The top channels were bolted in place and holes were made through the stiffener angles for the rods which support the reinforcing metal.

Fig. 14 shows the bracket end of one of these beams with its open web.

Fig. 15 shows the process of concreting the beams as well as the method of placing the reinforcing metal. One-half-inch steel bars are run through the holes in the stiffener angles at the top, bottom and middle of the beam on each side of the web. To these ½-in. bars are wired sheets of Kahn ribbed metal of 6-in. mesh. Concrete consisting of one part Portland cement, two parts sand and four parts fine broken stones is being placed on one side of the beam while the latter is lying on its side. Although not called for in the specifications, the surface of the concrete was finished practically as a granolithic surface and an excellent job of concreting was obtained. In this view will be noticed castings projecting from the concrete at about mid-height of the web of the floor beams. These castings are to receive the bottom lateral bracing, which is to be attached to them by means of pins in order that the bracing may be readily renewed when corroded. It was desirable to have the castings made of some metal which would be non-corrosive, as the castings themselves could not be renewed without breaking into the concrete and exposing the web of the floor beam. Several types of composition castings were considered and finally it was decided to use a casting consisting, approximately, of 70 per cent. aluminum, 3 per cent. copper and 27 per cent. zinc. This composition has a tensile strength equal to that of ordinary bronze and is probably less liable to corrosion on account of its small percentage of copper. This metal is known as Macadamite and is made by the United States Macadamite Metal Company, of Brooklyn, N. Y.

Fig. 16 shows one end of a floor beam in which the concreting has been completed. Here will be seen two of the aluminum castings for the connection of the bottom lateral bracing as well as the iron casting which is to receive the pin of the eye-bar hangers. As this latter casting is of relatively thick metal and projects only slightly beyond the concrete, it was thought unnecessary to make this casting of composition metal.

Fig. 13 shows further details and a comparison of the methods used for the protection of the city and street railway floor beams with concrete.

On the city floor beams the concrete protection was made

$4\frac{1}{4}$ in. thick on each side of the web. The steel reinforcement, consisting of Kahn rib metal of 6-in. mesh, was placed about $1\frac{1}{2}$ in. in from the face of the concrete and was wired to the $\frac{1}{2}$ in. square bars running longitudinally through the top, bottom and middle of the stiffener angles. The stiffeners were spaced at regular intervals to accommodate standard widths of reinforcing metal. At the tapered ends of the beams, acting as sidewalk brackets, the rods were continued, but the Kahn metal omitted and a lattice web used, which allowed good bond between the concrete slabs on the two faces of the bracket. The bottom flange channel, used mainly to resist blast action of the locomotives, was riveted to the flange angles with countersunk rivets in the hope that the countersunk heads, being less exposed to the blast, would last longer than button heads. The countersunk rivets were not chipped. At the top flange the protecting channel was bolted to the flange angles with brass bolts before the concreting was done. To guard against possible electrolytic action between the brass and steel, $\frac{3}{4}$ in. diameter bolts were used in $\frac{15}{16}$-in. diameter holes, the holes in the channel were countersunk on the top side, the spaces surrounding the bolts were filled with elastic cement, and lead washers were used between the brass nuts and the top surface of the channel. The beams were concreted while lying on the side, as shown in Fig. 15. After the beams had been concreted they were allowed to stand for some time in the bridge shop yard in an upright position, as shown in Fig. 16, and while the moisture was drying out of the concrete the latter would shrink away from the top flange to a slight extent. This action had been foreseen and provision made for grouting the top flanges, after the concrete had set. Holes 1 in. in diameter had been drilled every 4 ft. near the outer edges of the channels and grout was poured in through a long-nosed tunnel under a head of some six or eight inches. Grout consisting of two parts Portland cement and one part sand was first tried, but without success, as it would not flow properly. Neat Portland cement grout was next tried and found to flow freely for a distance of 6 or 8 ft. each side of the grouting hole. The top channel was removed from some of the beams while the latter were at the yards of the Boston Bridge Works, and in all cases where neat Portland cement grout had been used the grouting was successful, the voids in the concrete having been well filled.

During the rebuilding of the city's bridge the Boston Elevated Railway Company decided to place a concrete protection upon the floor beams of the street railway structure, and, at the

request of that company, the design of the protection was made by the engineering department of the city, the details being shown in Fig. 13. In order not to add too much dead weight to these beams it was decided to make the concrete only 2 in. thick on each side of the web and to encase each stiffener angle. The whole of the top flange and the top side of the bottom flange were protected. No protection was provided for the under side of the bottom flange, partly on account of limited headroom, but more especially because it was thought that the protection could not be held in place, owing to the blast from locomotive stacks, the tops of which come within a few inches of the beams, and also because of the likelihood of the concrete or mortar cracking at the edges of the flange and exposing the reinforcing metal to corrosion. Slabs or pieces of mortar falling upon passing trains would be a source of danger to passengers within the cars, as has been shown by experiences elsewhere. To hold the concrete protection in place at the top flanges, rivets were cut out from the outer gage lines at intervals of about 2 ft. and angles were bolted to the underside of the flange, a clearance of 1 in. being provided between the angles and the edges of the flange plates, and an equal or greater clearance being allowed at the under side of the flange. The concrete at each side of the web was held by Clinton wire cloth, 3 in. by 8 in. mesh, 8 and 10 gage wires, held by $\frac{1}{4}$-in. bolts through the web, holes for the bolts being drilled in the field and the bolts being provided with threads, double nuts, clips and pipe washers at each end to hold the wire cloth in proper position. A wire cloth reinforcement was placed around each stiffener angle and wired to the reinforcement on the web. Wooden forms were provided on each side of the beams, reaching from the bottom to the reinforcement angles at the top flange. Openings through which concrete was placed were left just under the top flange.

The concrete protection of the street railway floor beams was really a mortar protection, mortar consisting of one part Portland cement and two parts sand being used for the web protection and a grout made of 1 to 1 Portland cement and sand being poured in and around the top flange after the web protection had been put in place. All of the work in connection with the protection of the street railway floor beams was necessarily done in the field, as it was not feasible to remove these beams from the bridge. As their protection is of lighter construction than that of the city's beams, and was placed under considerable difficulty, owing to the constant passing of trains beneath the

bridge, it may be less durable than that of the city floor beams. The results obtained upon the street railway beams were very satisfactory, however; to all appearances the concrete is sound and continuous, without cracks or serious voids, the contact with the steel is good, and it is hoped that the protection will perform satisfactory service for many years. The only steel now exposed to corrosion anywhere beneath the floor is the lateral bracing and the channel stringers in the city's bridge and the track stringers on the railway bridge and the floor beam hangers of both bridges, none of which can be conveniently protected, and all of which, except, perhaps, the hangers of the railway floor beams, are easily removed and renewed.

Erection of the Three Boylston Street Bridges from the Contractor's Standpoint.

By Mr. Moses.

The three steel bridges described in the previous papers were all built and erected by the Boston Bridge Works, of Boston,

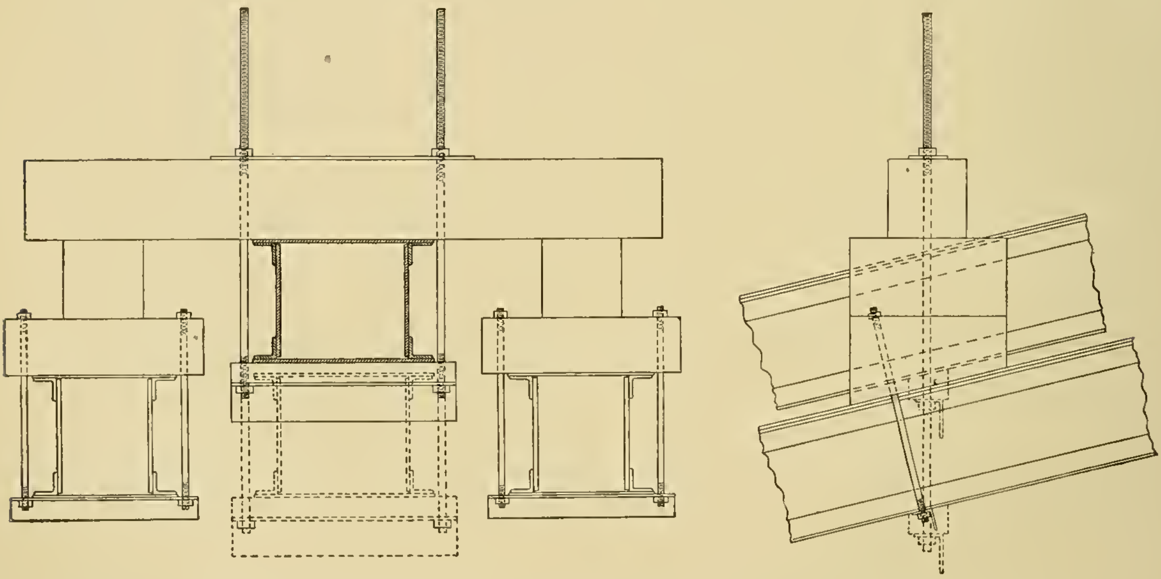


Fig. 17. Method of Temporarily Supporting Top Chords of Railway Trusses in Raised Position.

Mass. An account of the erection of the first bridge appears in Mr. Fay's second paper. The erection, in 1907, of the additional trusses and floor to carry the Boston Elevated Railway Company's tracks involved no special difficulties beyond the need of extreme care in avoiding any interference with the railway traffic below the bridge. The lower chords with the lower half of the posts and diagonals were erected in place. The top chords with the upper half of the posts and diagonals were erected about 2 ft. above their final place in order to give room for entering the pins

and driving the chord splices. They were supported temporarily by blocking and hanger rods arranged as shown in Fig. 17. When the pins were all in, and riveting completed, the nuts on the hanger rods were turned by men working simultaneously at all points, thus lowering the upper half of the truss. The diagonal bars were coupled and screwed up as the truss was lowered, and the post joints riveted when the truss was in its final position. The top bracing between the two outside chords was then replaced and the new spacing struts were riveted together. The new trusses were cambered to match the old trusses, whose outline was somewhat irregular. Temporary tracks were then laid to carry the street cars and fences built to keep the rest of the roadways safely closed. The sidewalks were kept open to traffic throughout the work.

The erection, in 1908, of the new city trusses was, on the other hand, a difficult and dangerous undertaking. The working room available was very limited. A city fire station at one end of the bridge prevented occupancy of the street to a large degree. At the other end of the bridge the sidewalks had to be kept open to give entrance to the stores facing the street, and the street itself could only be occupied for a short distance. No staging of any kind was possible below the bridge, the clearance between metal and trains being but a few inches, and all five tracks being in constant use, train movements averaging over one a minute at some hours of the day. Guy ropes for derricks were out of the question. Moreover, it was necessary to give opportunity to the city to change the parapets and repave the street adjoining the bridge. The telephone and electric light companies were also obliged to take up their old conduits and wires that had been carried by the old bridge and relay them, building new manholes and underground conduits to receive them. Similar work was done by the street railway company, besides laying their new tracks when the structure was ready to receive them. All this work had to be done during the erection period.

The necessity of doing the work in the shortest time possible was very great and the contractor was placed under a heavy penalty for every day taken in excess of the sixty days allowed by the contract. A corresponding premium was allowed for completion before the specified time. The work was deemed to be of too dangerous a character to be safely conducted at night. Great care had to be constantly exercised to avoid the possibility of falling tools, hanging ropes or projecting timbers that would be dangerous to trains, flagmen being kept constantly on

watch below. The smoke and steam from the trains and switch engines would also have made work by artificial light much more dangerous. Erection was, therefore, carried on by daylight only, two shifts of men, working from 4 A.M. to 8 P.M., being employed. As many men were put on the work as could be used, but the number was limited as one operation had to succeed another to an unusual degree. All steel work was completed at the shop before erection was begun, and the lumber for the floor was framed ready for placing before being brought to the site. A compressed air plant was installed to furnish power for drilling and riveting. The 100-ton hydraulic jacks used were tested at the shop in a machine built for the purpose, and two specially designed, movable, stiff-leg derricks were constructed. The erection foreman was furnished with unusually complete drawings and shipping lists, and the draftsman who had checked the drawings was kept on the job.

The first operation required after removing the temporary tracks from the bridge was raising the entire structure about 7 ft. vertically. This was done by constructing a framework of heavy beams at each end post (Fig. 18) that formed cantilevers projecting beyond the trusses. Two 100-ton jacks were placed, resting on the abutments and bearing up under each set of beams. All four corners were jacked up simultaneously, the blocking under the truss pedestals being carried up under them with great care and kept constantly tight with wedges. The load lifted was over 700 tons and about the limit of the jacks' capacity, and the possibility of failure of a jack at any moment had to be provided against.

The sharp skew of the bridge caused one end of most of the floor beams to bear on the abutments. A timber bent was built on each abutment, straddling the floor beams. Rods attached to the beams passed through the caps of these bents. These rods were threaded and the beams raised by turning nuts on top of the caps. (Fig. 19.)

After raising the bridge it was necessary to shift the trusses laterally as much as 10 in. in some cases. This was accomplished by setting a jack on a slope, as shown in Fig. 20.

When the trusses were in correct position, steel pedestals were placed under the center trusses. (Fig. 21.) These pedestals furnished permanent supports for the center trusses, the outside trusses being supported by new concrete and granite extensions to the abutments that also inclosed the steel pedestals. Before this masonry could be built, the blocking under the outside

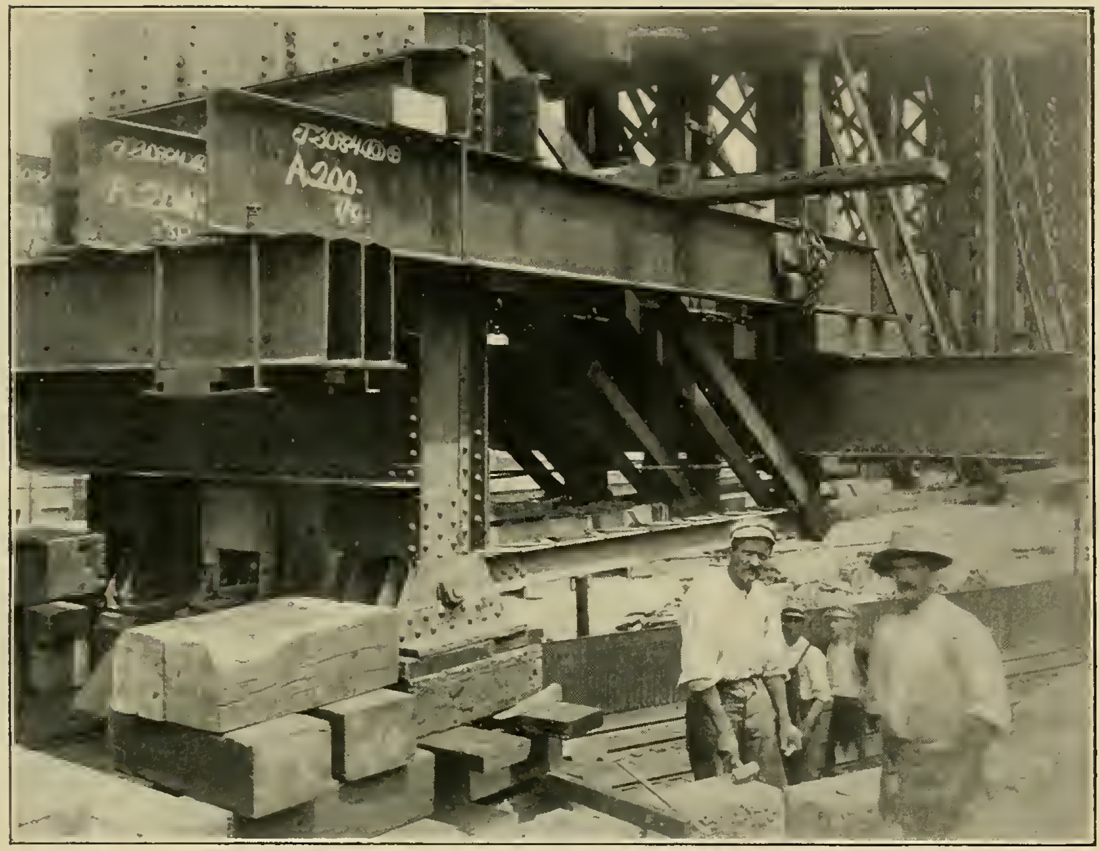


Fig. 18. Temporary Framework for Raising Ends of Trusses.

Fig. 19. Temporary Timber Bent for Raising Abutment Ends of Skew Floor Beams.

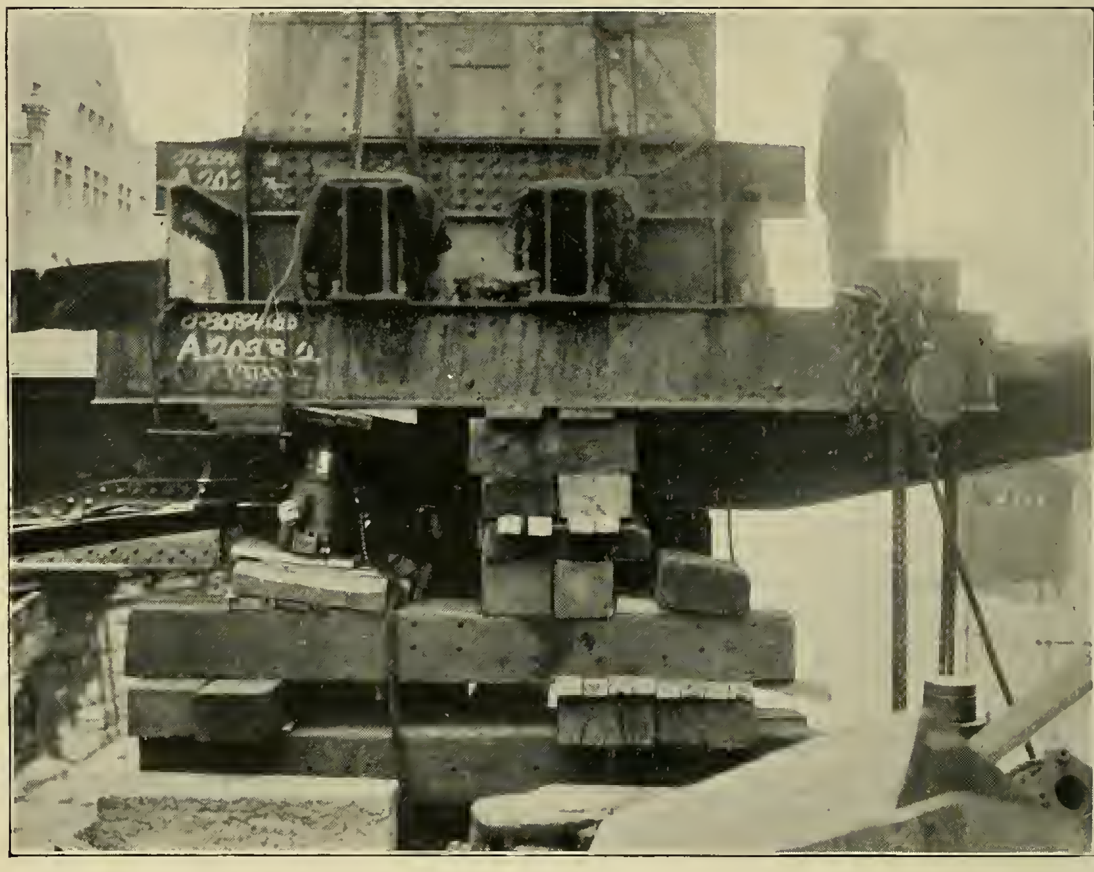


Fig. 20. Jacking Trusses into Position Laterally after Raising Bridge.

Fig. 25. Erection of New City Floor Beams.

Fig. 26. Stiff-leg Movable Derricks at Work Erecting New City Floor Beams.

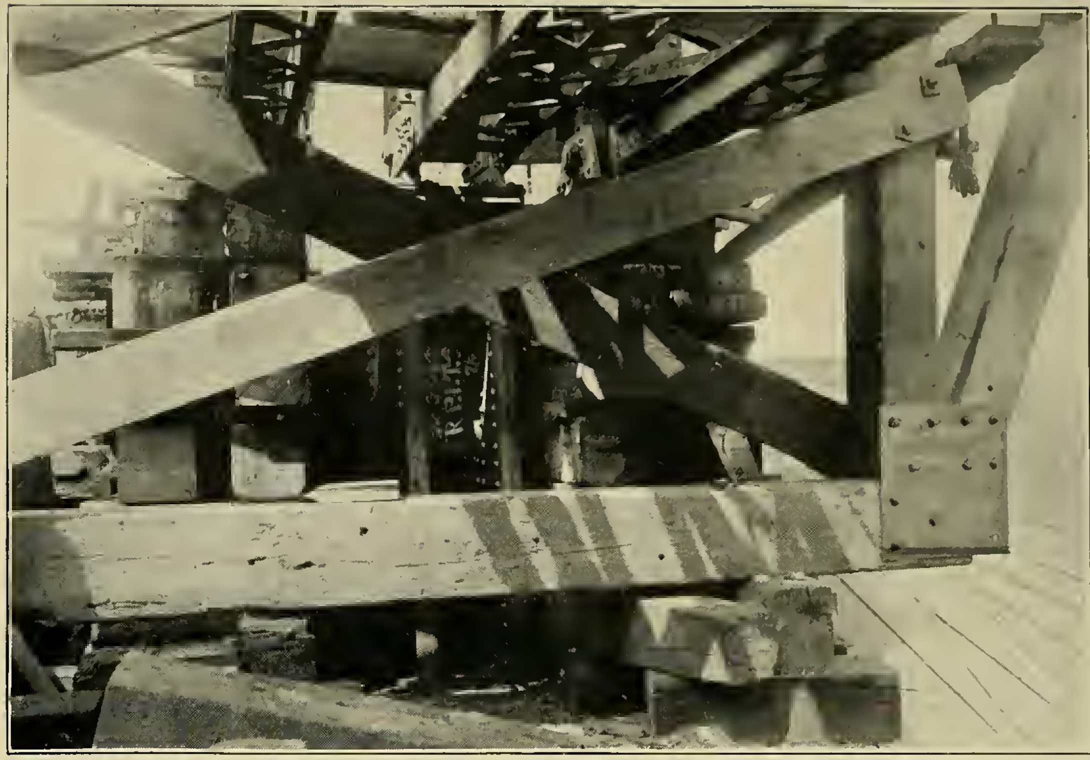


FIG 21. PERMANENT STEEL PEDESTAL SUPPORT FOR CENTER TRUSS.

FIG. 22. TEMPORARY BRACING OF TRUSSES DURING RAISING OF BRIDGE.

trusses had to be removed, and before this could be done the weight of the two outside trusses had to be transferred to the center truss. When this was done, and the blocking removed, the structure would evidently be in a very top-heavy condition. Every precaution possible to prevent the trusses overturning or buckling at this time was deemed necessary, the contemplation of such an accident with its likelihood of causing a serious train wreck as well as the destruction of the bridge itself amply justifying the consideration of all conceivable methods of handling the erection at this stage. The plan adopted represents the result of much study of many schemes.

Timber portals were constructed at each corner of the bridge. These portals were bolted to the top chords and were supported on the front edge of the abutments in front of the new masonry. (Fig. 21.) Additional struts and guys were provided (Fig. 22) where possible, but the curvature of the top chords, combined with the sharp skew of the bridge, made any bracing from truss to truss impracticable. The abutments were built as quickly as possible and the truss shoes wedged up on them so as to give stability, but not sufficiently to bring the truss weight on the new masonry before it had set.

While the new masonry pedestals were being built under the outside trusses, the old floor beams were removed, and floor beams for the street railway track that were erected in 1907 were lowered to their former level. This work was done by the stiff-leg derricks advancing on to the bridge from either end. The old beams had to be cut in pieces to free them from the trusses. The street railway beams were supported from the center trusses by new hangers. As fast as they were lowered, the steel stringers for the tracks were put in place and they, in turn, furnished supports for the advancing derricks.

The bridge having been raised and the old floor removed, or lowered, all portions of the outside trusses, except the top chords, were removed and replaced with new material. The weight of these trusses was first transferred to the center trusses by blocking and hanger rods, as shown by Fig. 23. A short block was placed on the center truss. On top of this a transverse timber was placed with hanger rods that supported blocks under the outside chords. This blocking was placed at each panel point (Fig. 22) and by screwing up on all the rods simultaneously the weight of the outside trusses was transferred to the center usses, and at the same time the outside trusses were relieved of all strain. It was then possible to pull out the pins and remove

the old posts and diagonal bars. About 150 tons of old material were removed in this way and replaced with about 300 tons of new material. When the outside trusses had thus been renewed, they were lowered to their bearings on the new concrete and granite pedestals. The blocking was then rearranged, about as shown in Fig. 17, and the center truss was raised and adjusted to correspond with the camber of the new outside trusses. It will be recalled that the center truss had all its diagonals adjustable and was originally erected to match the somewhat distorted outline of the old trusses.

The next operation was the erection of the new floor beams. The longest beams were 80 ft. long, and weighed, with their concrete covering, about 22 tons each. They had been concreted at

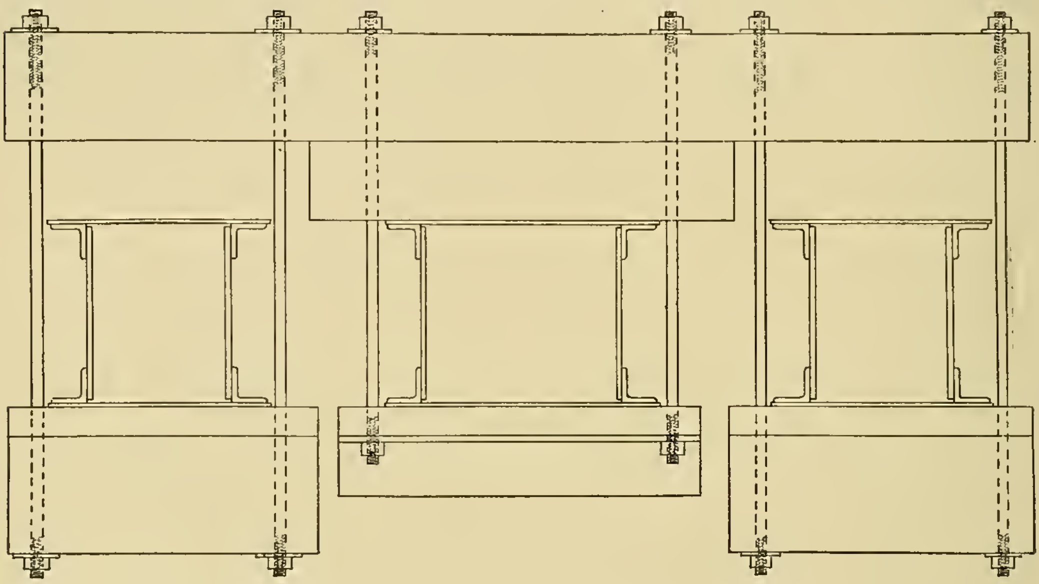


Fig. 23. Method of Temporarily Supporting Top Chords of Original Trusses upon Top Chord of Railway Truss.

the shop some time in advance and were loaded on a special train of cars and brought to the bridge on one of the tracks underneath at an early hour on a Sunday. From these cars they were hoisted at available times between the regular train movements on the other tracks. Both derricks were attached to each beam in turn, the beams raised from the cars, swung about and hoisted into place. (Figs. 24 to 26.)

The floor beams that carry the street railway tracks were concreted next, some 35 yd. of concrete being placed for this purpose. The lumber for the floor, amounting to about 100 000 ft., was then laid; two coats of paint given the entire structure; and the old curbs and scuppers replaced. About 500 ft. of old fence was repaired and replaced on the bridge and new pipe railings attached to the trusses. There were in all 5 500 old

rivets cut out, 2 500 new holes drilled and 6 500 new rivets driven during the erection of the bridge. The changes in the abutments required 125 yd. of concrete and granite. Some 40 tons of steel were manufactured for erection purposes. The entire work was safely completed ten days ahead of the contract time.

DISCUSSION.

Mr. Henry Manley. — When the bridge was built the headroom allowed for the railroad was only 15 ft. Since then the bridge has settled a foot or thereabout, and the railroad tracks have settled correspondingly. In the reconstruction a portion of the lost headroom has been regained without raising the approaches to the bridge. This is an important matter as the bridge cannot be raised without great expense and inconvenience, as the whole surrounding area, buildings and all, has gone down together. It is not desirable to still further depress the rails as they were uncomfortably near high-water mark to begin with.

I think an explanation of how the additional headroom was botained would be interesting.

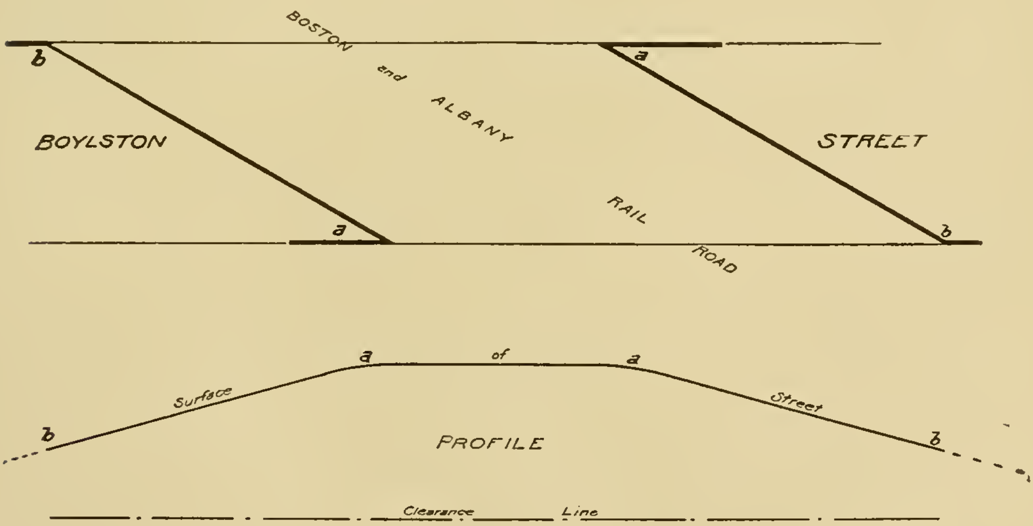


Fig. 28.

Mr. S. H. Thorndike. — Mr. Manley has spoken of the settlement of the whole region in the neighborhood of the bridge; the records show that it is considerable. The engineer who gave lines and grades for the masonry, which was erected in 1888, remembers it as a particularly accurate job, one of the cases where the contractor and the engineer worked together and the entire structure was set exactly at grade. So there is good datum to start from. In dealing with the masonry during the

past two years, it was found to be $8\frac{1}{2}$ in. below grade at the acute angle and 16 in. at the obtuse angle. I will draw a diagram on the blackboard.

Note that the acute angles (of the masonry) at *a* and *a* are carrying heavier reactions from the bridge and lighter loads from the filling than the obtuse angles at *b* and *b*. Since the obtuse angles went down most, the weight of the filling itself must be the dominant factor which is causing this settlement. The conditions below ground must be singularly uniform since the settlement at the two points *a* is the same within half an inch; these two points are equally loaded, but are quite disconnected and separated by the entire width of the railroad. Again, the settlement at the two points *b* is the same, though they are still more widely separated and have settled under their heavier load nearly twice as much as the points *a*. In 1888 the street was laid out level for the entire length of the bridge, from *b* to *b*. In 1908 the unequal settlement was utilized by laying out the street on a gradient at each end, from *b* to near *a*, the central part only of the bridge being level. The floor beams between *a* and *b* at each end being shorter, were made shallower than those at the middle; the clearance line was kept at substantially the same grade throughout the bridge; and so to-day there is full 6 in. more clearance over the railroad than at any previous time in the history of the bridge.

Mr. Desmond FitzGerald. — Is that action going on now?

Mr. Thorndike. — The levels taken nearby show it is going on to-day.

Mr. William Parker. — Is that settlement any more than Mr. Freeman has told us that the whole of Boston is settling?

Mr. Thorndike. — Mr. Freeman's settlement takes one hundred years to go a foot. This settlement was $1\frac{1}{2}$ ft. in twenty years.

Mr. FitzGerald. — There is one question I should like to ask. How was that concrete protection which was put on top of the street railway floor beam held in place?

Mr. Fay. — The concrete protection had nothing to hold it except the angles bolted to the under side of the flange. The vertical legs of these angles extended as high as the top of that concrete — really mortar, not concrete — so that the mortar is actually held in a trough.

Mr. FitzGerald. — That mortar covering is 2 in. thick?

Mr. Fay. — About 2 in. thick.

Mr. FitzGerald. — It is a question whether a water-works

man ought to say a single thing in regard to such a question as this before us. But naturally my mind is interested in everything connected with the old Boston & Albany Railroad, especially as I built a great many abutments and some bridges over it myself. It seems to me the community was very fortunate in having the reconstruction of this bridge in such good hands — men who thought carefully of every little detail. It seems to me that the problem was very intelligently handled, although I am comparatively rusty and a poor judge with regard to those things now. The way in which the concrete protection was placed in connection with the floor beams seems to me excellent, and all the little details connected with it, especially where metals of different kinds were brought together, were extremely well thought out. It seems to me it shows very strongly the great advantage of putting all such things in good, scientific hands from the very beginning. You can imagine what would have happened if the reconstruction of a bridge of this kind had been put into the hands of ordinary politicians appointed by the mayor. The thing would have been rebuilt as it was built before and probably would have another short term of life.

PRES. J. R. WORCESTER. — It is interesting to notice the fact that the speakers several times referred to this as a case of concrete reinforcing steel. We are more used to its being twisted the other way now-a-days. I think in this case it is a proper use of the term, for while the concrete may not exactly increase the strength, it was certainly put there to increase the life. There is another point to which I wish to call attention, and that is, there didn't seem to be any great amount of difference, as far as I could judge from the description, in the way that iron and steel lasted in this instance, and I should like to ask Mr. Fay whether any particular difference was noticed.

MR. FAY. — It is hard to say what difference, if any, there was, because the conditions under which the two existed were different. The iron was in the floor beams, while the diagonals of the trusses were of steel. The floor beams, I think, had gone very rapidly during the last year or two of their life; that is, it is my belief that, after having reached a certain point of corrosion, the destruction was hastened by the pounding and hammering of the street cars, so that the fact of the flanges being broken off, and, as in one instance, of the diaphragm connecting the two webs of a beam being broken, was due in large part, in my opinion, to the pounding effect of the car traffic. On the other hand, the steel diagonals of the trusses had no such impact or

pounding to contend with and their destruction is simply a case of straight corrosion. Generally speaking, wrought iron will stand up very much better than steel, as shown in the case of the bridge on West Newton Street, over the Boston & Providence Railroad, where the traffic is nearly as heavy, though not quite, as it is on the Boston & Albany Railroad. That bridge was built in 1872 and it is good for some few years yet. It has a clearance of 18 ft. as against 15 ft. at Boylston Street. Generally speaking, it is our experience that wrought iron will last considerably longer than steel; just how much it is hard to say.

Mr. FitzGerald. — Was any part of this work carried on at night?

Mr. Fay. — Not after 8 o'clock. The work was carried on from 4 in the morning till 8 at night during July and August. I may say that the contractor was working under a penalty. He was allowed sixty days, but the work was so excellently handled that it was done in fifty days instead of sixty, so that a bonus of ten days was earned.

Mr. FitzGerald. — Anything drop on the track?

Mr. Fay. — Nothing of any size, except one piece of timber 4 in. by 4 in. in size and about 3 ft. long, used in connection with the forms for concreting the street railway floor beams. Two flagmen were on watch constantly to see that no harm came. Of course, wedges and tools and small articles of that sort fell, as well as a considerable number of rivets, but nothing of large size like a heavy timber was dropped on the tracks. There was one accident to a workman, who fell from the staging on the top of one of the trusses, struck on the staging at the level of the bottom chord of the truss, and fell from there down on to the track. Fortunately, he was not very seriously injured.

The President. — Professor Spofford spoke about Bessemer steel as being (I forget his exact words) a risky sort of metal. It seems to me that steel that will show the results attained by those eye-bars on full-sized tests is something we need not be very much afraid of. I wish we could do it every time.

Mr. L. S. Cowles. — Concerning the question of Bessemer compared with the open-hearth steel, it strikes me that where the steel is subject to impact, the Bessemer steel is less favored. We had a case of building work where in an I-beam a couple of shelf angles were broken off when they would not have been had it been open-hearth steel. Of course, in the rolling, the metal is undoubtedly more or less injured. Where impact is to be considered I should say the open-hearth is preferable.

Mr. FitzGerald. — Mr. Schwab has stated that in ten years from now steel will all be manufactured by the electrical process.

A Member. — I think all of us had a good chance to see that in the wire nails used for shingling. Use wire nails and in five years your shingles will be flying all over the neighborhood.

A Member. — Isn't the question of Bessemer versus open-hearth steel really a question of phosphorus? I have known beams to break in two as the result of being dropped from a wagon to the ground.

The President. — I think the member who has just spoken is right that phosphorus is generally the element in Bessemer steel that is dangerous. But I think that really the distinction between the two processes is rather that by the open-hearth process it is possible to control the exact chemical composition of the steel, whereas, by the Bessemer process, it is a little more doubtful what the result will be. They haven't the chance to vary the composition and depend more upon the raw material.

Mr. Moses. — I might say in regard to Bessemer steel: These eye-bars in the Boylston Street Bridge were Bessemer, and some other Bessemer eye-bars, bought about the same time and used for the Fitchburg Road, were subjected to an unusual test. They were struck by a train in a derailment, and the eye-bars, some of them, were bent edgewise at an angle of 45 degrees — practically a sharp angle — without a sign of fracture. The heads in that case were split open, but that wasn't surprising considering the blow they got. But the bars stood this strain as well as any open-hearth steel could do. I doubt whether Bessemer or open-hearth has much to do with it. It is probably safer to manufacture by the open-hearth process. There is Bessemer steel that will probably stand as well as open-hearth steel. I don't know what causes these hard places in the steel, but we do find them. I have known a plate 2 ft. wide to split into two layers. They don't generally split until you come to manufacture them. You find it out then. You can't punch them without splitting them.

The President. — I think the danger of shock is further illustrated by the fact that almost all railroad rails are Bessemer up to the present time. Perhaps in the future they will be open-hearth, but they have stood the test pretty well.

Professor Spofford. — In connection with my remarks upon Bessemer steel, it seems to me that the whole question of Bessemer steel as compared with open-hearth consists in the

greater uncertainty of results. You may get good tests of Bessemer steel, but it doesn't follow that all the rest of the output will be good. The results are not as uniform as with the open-hearth process. The open-hearth is supplanting Bessemer very rapidly in structural work, and even Sir Henry Bessemer thinks himself that he should have continued his experiments in open-hearth instead of going off and developing the Bessemer process. I looked at the tests of Bessemer steel in examining this bridge, and I realized that it was good Bessemer steel. But I am not in favor of Bessemer steel for structural work. The unit stresses were such that it wasn't wise to keep the bridge as it was, even if it was built of open-hearth steel. Still, to my mind, the fact that it was built of Bessemer steel was another element against it.

THE PRESIDENT. — I would ask Mr. Fay if he made any calculations as to the maximum unit stress ever developed in those corroded bars?

MR. FAY. — Such calculations have been made, Mr. President, and with a very small, uniformly distributed load of, say, 20 lb. per square foot of floor, and with only a single 26-ton car on each track — and we frequently get two cars on that bridge on each track — we found a number of instances in which the stresses must have been in the neighborhood of 20 000 lb. or so. That, however, is for an extremely small load. There was one instance where one bar, to which I did not call attention, was bent so it could not carry the normal stress; its mate in that particular panel was carrying a stress even under this small load of 43 000 lb., assuming that it was doing half the work of the double truss. I should say that probably the actual stresses obtained in the diagonals under everyday traffic, with the car tracks full and with the roadways reasonably full of teams, and the sidewalks having such foot travel as is likely to come on the bridge, might easily have reached 30 000 lb. in many cases. And, of course, in the particular case where there was a bent bar out of service in a panel, the stress must have been very much higher. But the stresses in those diagonals were not as high as you might think, because, as Professor Spofford said, many of the diagonal bars had an excess of section originally.

[NOTE. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by March 15, 1910, for publication in a subsequent number of the JOURNAL.]

THE ENGINEERING TRADES ON THE PACIFIC COAST.

By George W. Dickie, Member of the Technical Society of the Pacific Coast.

[Read before the Society, November 26, 1909.]

For some time I have felt growing upon me the necessity of writing a paper on the above subject; to me the subject is not an agreeable one, nor is it likely to be so to most of those who may listen to me read this paper or read it themselves afterward. My connection with the engineering trade on this coast began in 1870, and still continues. During that period of nearly forty years, mining machinery and marine engines for our coastwise shipping formed the most important work for our engineering establishments.

The development of the mining industry of California and Nevada brought to the mechanical engineers of the state many problems requiring much original mechanical work in their solution. The treatment of ores required the combination of mechanical skill and chemistry to solve the problems involved, and the many contrivances designed and made here for the extraction of the precious metals from their native matrix of rock made the foundries of San Francisco famous for the machinery required in the treatment of all kinds of ores.

Hydraulic mining, which required large quantities of water to be carried sometimes under great pressure, and at a cost that would make it profitable as a means of dislodging and disintegrating huge masses of earth and gravel, originated the building of riveted iron pipe and the making of the powerful hydraulic nozzles called "giants."

The utilization of mountain streams, where the pressure was more in evidence than the volume, forced the hydraulic engineers into devising simple but effective water wheels that have made water power possible in many regions of our mountain ranges where it was not so by any of our then existing methods.

Between 1870 and 1880 hoisting and pumping works for deep mining were developed in our engineering shops to a remarkable degree, both in size and efficiency. Air compressing also for deep working received much attention from our mechanical engineers; the first two-stage compressors were built in San

Francisco. In marine engineering the progress was equally swift; the first triple expansion engine built in the United States was built here. The first quartz mill that went into South Africa was a product of our designing and constructing skill.

Thus it will be seen that during the last thirty years of the nineteenth century there was no lack of engineering enterprise amongst us, but during the past ten years there has been a great falling off in the mechanical engineering work done here.

Establishments that employed thousands of men are practically fallen into idleness, while the machinery importing houses have enlarged their business and are not only selling machines produced in other states, but are planning and carrying out machinery installations that were not considered within their scope a few years ago. The suddenness of the decline, and in some instances total extinction, of what were flourishing industries a few years ago has bewildered many of those who looked upon these industries as a permanent part of the achievement, resulting from sixty years' endeavor, of the able men who brought them into existence.

The writer began to see the dangers confronting these industries about 1896 and warned those interested. The first symptom was a general condition of unrest among the men; wages were higher here than in any other state, — at least as much higher as to make up for the cost of transportation of machinery made elsewhere, — yet the leaders were able to persuade the men that any demands they made would be allowed after a show of fight. In this way their minds were poisoned to such an extent that for several years, or up to 1901, the conditions were very trying. Men became indifferent, and what work they did, like all work forced from unwilling hands, was badly done and cost much more than it did when the men were doing it under normal conditions; this prevailed to such an extent that the great strike of 1901 was accepted by the employers as a relief from conditions that had become intolerable. This strike in the metal trades lasted about eleven months and both sides were exhausted; neither side ever fully recovered. A large part of the business that naturally belonged to San Francisco engineering works went permanently into the hands of the commission houses representing establishments in the other states, which could lay down machinery here, with freight and commission added, at less cost than it could be made for here. This condition has been aggravated by the conditions following the disaster of 1906, the efforts to recover from which, while demonstrating the

courage of our citizens, has still further intensified the difference in cost of manufacturing here as compared with other states.

The opening of the Panama Canal will have an important influence on the cost of transporting machinery from other states where it is manufactured under different conditions, economic and otherwise. This event will be powerful in forcing conditions here into correspondence with conditions in other states; either this correspondence will ensue, or engineering establishments on this coast will have to be abandoned. It is to be hoped that another destiny awaits us as the future opens up opportunities, and that some way will be found to enable us, those who work with hand and those who work with brain, to unite in some method whereby we shall be able to produce work of all kinds as cheaply as other states of the Union, under conditions that will raise the status of the workman and at the same time give remunerative employment to the brains and capital of our people.

In the Eastern states much has been done of late among the metal trades to render the workmen more efficient and thereby increase their product. The principal improvement has been in the science of cutting metals. The high-grade steel now used in the construction of machinery has brought about a great change in the methods of shaping the blanks that come from the forge. Fine smithing is no longer profitable, and rapid cutting has taken the place of skillful hammering. A great many of the establishments in the East have adopted tools and methods of handling them that leave us far behind. The progress made of late years in the art of cutting metals is one of the marvels of this age of steel. In this country no one has done more to develop the science of metal cutting and the art of applying it in the shop than Mr. Fred W. Taylor, of Philadelphia. In this work he has been ably seconded by such men as Mr. Barth and Mr. Gantt. After an immense amount of labor and experiment, extending over several years, these men have been able to produce practical solutions of the mathematical problems growing out of the laws governing the effect on the final result of the conditions under which the work is done.

Mr. Taylor gives the following twelve variables that constitute factors in the problem of computing what should be standard time required for any task in machine work:

a. The quality of the metal which is to be cut, that is, its hardness or other qualities which affect the cutting speed.

b. The diameter of the work.

c. The depth of cut or one half the amount by which the forging or casting is being reduced in diameter in turning.

d. The thickness of the shaving, or the thickness of the spiral strip or band of metal which is to be removed by the tool, measured while the metal retains its original density; not the thickness of the actual shaving, the metal of which has become partly disintegrated.

e. The elasticity of the work and of the tool.

f. The shape or contour of the cutting edge of the tool, together with its clearance and lip angles.

g. The chemical composition of the steel from which the tool is made and the heat treatment of the tool.

h. Whether a heavy stream of water or other cooling medium is used on the tool.

i. The duration of the cut, that is to say, the time which a tool must last under the pressure of the shaving without being reground.

k. The pressure of the shaving or chip on the tool.

l. The changes of speed and feed possible in the lathe.

m. The pulling and feeding power of the lathe or other machine at its various speeds.

The effect of these twelve variables upon the following three questions, directly affecting the economy of the shop, was the problem to be solved:

What depth of cut shall be used?

What feed shall be used?

What cutting speed shall be used?

It required years of experiment before sufficient data were collected to enable these questions to be approximately answered and the mathematical problems reduced to the scope of a special slide rule that could be used in the every-day shop work.

Out of this research has grown what is known as the instructor, task and bonus system, which has been adopted with very satisfactory results on the economy of production by many shops in this country. A manager who understands and can use this system is enabled to determine the possible work that he can get out of every tool in his establishment and to determine on the best tool to get when he adds to his plant. The majority of people, however, including managers, foremen and workmen, prefer to work at the speed and in the manner they have been accustomed to, and it requires some kind of stimulus to change the methods that are in use.

The inertia of men in all departments of an engineering

establishment, from the manager down to the humblest laborer, is the principal object that stands in the way of any system that demands continual alertness in making the most of every minute of time; hence the necessity of a bonus or reward for every one interested when the task that has been set after careful experiment has been accomplished; but in reaching the standard time required for any job or task, the possibility of rapid accomplishment must be demonstrated in detail to the workmen by an expert who can actually do every part of the task within the standard allotment for each part. This man is the instructor. When a workman succeeds in completing his task within the time set for it, he is entitled to a bonus, which is usually from 20 to 50 per cent. of that time; if he takes more than the allotted time, he gets only his regular pay. In setting these tasks it is customary to specify the manner of performing all the operations and to supply the proper tools to the workman; this requires a highly trained staff to insure success. Mr. Gantt claims that when 25 per cent. of the workmen are bonus men, they, with those who are striving to become bonus men, control the sentiment and a strong spirit of coöperation develops, and this spirit of living up to the standard set by an expert, which is the only way that a bonus can be earned, benefits the employer by the production of more work, better work, cheaper work; it benefits the workmen by giving them better wages, increased skill, better habits of work and more pleasure and pride in their work; this latter benefit to the employee is even more of a benefit to the employer, for it insures good work.

This system has been extensively adopted in the Eastern states and has generally resulted in a larger and better product produced at lower cost, while the earnings of the workmen have been increased.

That the system outlined above can be adopted in the engineering shops on the Pacific coast is open to argument. Where manufacturing is done on such a scale that thousands of the same piece have to be produced, giving an opportunity for careful experiment to determine what should be the standard time for its production, and where the cost of such experimenting and the expert's time would form a very small percentage of the cost of production, such a system will show great economical advantages; but where new problems come up every day, and manufacturing in the sense of duplicating parts by the thousand does not exist, the system so successfully developed by Mr. Taylor and his associates will not show any advantage; this latter

condition is the prevailing one on the Pacific coast, where, under present conditions, it is impossible for our shops to compete in any line of business that can, because of wider markets, be carried on in the East as manufacturing.

The system is also defective because it cannot be applied to the general work of a shop, except, perhaps, in the assembling of small machines that involve only the work of one man on each task, or subdivision of the work involved; where the assembling of large machines, or engines, involving the work of many hands, forms a large part of the work of an establishment, the task and bonus system cannot be applied, for it would be impossible to compute a standard time for each workman and set him a task; in such cases a standard would have to be set for a number of men collectively, and should they fail to meet the standard set, they would collectively lose the bonus, although individually they might each have been capable of doing their proportion of the task. I believe that the application of this system must be largely, if not entirely, confined to the work done on machines that are especially adapted to the work in question, and where the work is the duplication, in large numbers, of pieces that can be standard in form and dimensions and also in quality of material.

A knowledge of the working of such a system should, however, be of great value to the manager of a general engineering works, as it would enable him in making estimates of the cost of work to determine, with some approach to exactness, what should be the possible efficiency of his tools on different classes of work; a careful study of what is possible for every tool, and every man in the establishment should be always available to the manager of an engineering shop if he is to keep abreast of the possibilities that lie within his management. Such knowledge is worth much labor and experimenting to find out, and is really the foundation of all correct estimating.

The tool part of this problem, in conjunction with the operator, is, with our present knowledge, — thanks to Mr. Taylor and others in the same field of research. — to a certain extent solvable. The cutting power and endurance of tool steels, the possible speed under known conditions, the pulling power of belts, how these are affected by the character of the material operated on, and all the variables that enter into that part of the problem, the labors of such men as Taylor, Gantt, Barth and others have brought within the scope of the ordinary manager's ability, and they can be figured out with a reasonable degree of accuracy.

But how about the other men that don't work with tools that have known speeds and adjustable feeds? In the general engineering works they outnumber those on tools at least three to one. The work of this other man is the unknown quantity in all estimates of labor; the only certain thing about him is his rate of pay per hour or day, the work to be accomplished being an unknown quantity and the purchase of the man's time being only an option on something the amount of which will only be known after delivery. As the labor part of any estimate for machinery will be from 40 to 80 per cent., depending upon the simplicity or complexity of the work, and as the rate of wages is considerably higher than it is in the Eastern states, and with a much more contracted market, cutting out manufacturing in the economic sense, how is it possible for our engineering establishments to reach and maintain a satisfactory place in the industries of the Pacific coast?

From a long experience and after much study I reached the conclusion some fifteen years ago that there was only one solution to this problem if such industries are to live and prosper, and that lies in an entire change of attitude towards each other, of the employer and the employed. They must become partners in the labor part of every estimate. The advancement in general education, with the opportunities open to every one for acquiring knowledge relating to technical subjects, enables the workman to understand estimates made for the work they are engaged in. I think that it is safe to say that from a body of workmen employed in any of our engineering establishments there could be selected men to represent the body to which they belong that would, in a very short time, be just as competent to estimate on the labor cost of machine work as the manager of the works or any other officer that does the estimating; they would really have the advantage, for they can, in a measure, make the result fit the estimate. It is an evident fact that any machinery made on this coast to compete with the same machinery imported from other parts of the country must be produced for the same cost, plus freight charges, and must be sold here at the same price; and as transportation cheapens, which it will do materially on the opening of the Panama Canal, the conditions will be worse than they now are, unless the labor costs can be equalized between the East and the West. In all classes of machinery that have to go into general competition, the price obtainable here is easily known. The manager of any of our engineering establishments knows, or ought to know, what the materials required for the

production of any given piece of machinery cost; he knows, or ought to know, what the percentage of general expense or overhead charges, which includes cost of management and every other operating cost not charged directly to this particular thing, is. He knows what per cent. he must add for profit. But the largest item — the cost of labor — he must assume from his experience, which may mislead him. And the trouble here to-day is the inability of those operating engineering works to establish the cost of labor. I used in estimating, of which I have done a great deal, to divide the work to be estimated on into as many units as possible, the more the better; then take each unit and carefully figure out the hours' work that would be required on the various operations to complete it — going on my own knowledge and the record of other work that came near it in character; then I would group these units into a part that would appear in the estimate as a distinct portion, that could be placed in the shops under a special number and its actual cost compared with the estimate. In that way many years of experience enabled me to estimate closely, when conditions were constant, which of late years have been far from the case. Many a time I have watched the progress of some piece of work, comparing it regularly with the estimate. I would often go to the leading man when the cost would come dangerously near my estimate and say something like this to him: "Jimmie, when will you get done with this, and can't you reduce the force and do just as well?" To which he might reply, "I think, Mr. Dickie, we will be able to complete this job to-morrow," and I would go away, satisfied that my estimate was all right, dismiss it from my mind, and I might not see the job again for a week; but just as likely as not when I did see it again, Jimmie and his gang would be still at work on it and my estimate all gone to smash. Now why should not Jimmie and his gang have something to say about the cost of labor for that job and agree to accept that cost as their compensation at the time the estimate is made? In other words, I would suggest the system for the Pacific coast that I have long advocated as a means of enabling our shops to meet the outside competition, — that of taking the workmen, or their representatives, into counsel when the estimates are made for any work, and have the men or their representatives, when satisfied with the estimate for labor, accept the amount so estimated as the amount that would be paid to the workman for all the labor included in the estimate. This would extinguish the wage question, and with it the uncertainty in regard to the outcome of

any contract, and would give capital the necessary confidence to engage in the work of producing here the machinery needed on this coast. It would avoid all fighting with the unions and the loss and distress entailed thereby. I have pointed out what is being done in other parts of the country to insure a known output from a given number of men and tools. A knowledge of that work would be a great help to the manager of works here, and perhaps more so to the men, who, if they are to abide here and live by the work they have been trained to do, must find a way to do their work at such a cost as will enable those having work to do to place it in the works that gives them employment. I have described my plan in detail elsewhere and need not go into details here. Briefly it is this: The men in each department of the works would select one of themselves to represent them in contracting for work. These men would be chosen for a certain time, say one year; that is, there would be an opportunity for change every year. So that the best men in each department would form the Works Committee in all dealings with the office, and a contract signed by them would be binding on all the men. This committee would also rate all the men in the various departments, the rate in no case to be more than the prevailing rate of the district.

In making all estimates for work, the factors forming the estimate should be:

First: The actual cost in the works of all materials required for the work being estimated on.

Second: The general expense to be borne by the work in question. This includes all actual costs not charged directly to specific work, such as expense of operation, management, maintenance of plant, power, interest on borrowed money (not capital), taxes, advertising, foremen and all men, such as watchmen, sweepers, etc.; in fact, everything not charged directly to the work in progress, the item known as overhead charges. The *pro rata* of this charge would be the proportion that the work being estimated upon would bear to the average year's output.

Third: The actual cost of labor which the manager would estimate on, according to his experience, which would be carefully gone into by the workmen's committee, and, if necessary, changed in accordance with what was mutually agreeable; and, when satisfactory, the total amount of this item would be the sum to be paid to the men.

Fourth: Profit, which would be a percentage on the sum of the three foregoing items. This percentage should be known

to the workmen's committee and they should be satisfied about it.

It might be that the sum total would be more than in the judgment of the manager would secure the work; in that case he would call in the Workmen's Committee and explain his reasons for thinking their price would not secure the work, then arrange either to deduct something from the labor cost, or the profit item, or both, as might seem best, or decide to let the work go elsewhere.

When work was secured, the contract for the labor item would be signed by the committee and its amount posted up in the works; the amount for labor would be credited on the books to the labor account; payments would be made to the men monthly, or as might be considered best mutually, these payments to be on the wage rate fixed by the committee less 10 per cent., each man's time being kept, as is the present custom, and the amount thus paid out charged against the amount of this contract in the labor account book. On the completion of the contract, the amount remaining would be carried over to the labor surplus account, from which dividends would be paid from time to time, the dividend being a percentage on the amount that each man had been paid in advance wages.

By this system the earnings of any man do not depend on any job, but it is the share of the surplus from all the work done during the year or six months that the dividend period covers. It would meet the idea of the trades unions that the strong should help the weak. It gives to every man the dignity of a contractor. The trades unions would then be able to perform a great and beneficent work, and labor would always have the chance to meet or not meet the price that the market and the times afford. Every man would be directly interested in the product of himself and his fellow-workman. It would not be like the task and bonus system, where a man must reach and pass a mark that has been set for him in order to get anything more than the prevailing rate of wages; but whatever he or his fellow-workmen may do that is better than the estimate will help to swell the dividend. Something like this is the only hope I see for the future of the engineering shops of the Pacific coast. We must produce work here at a cost that will keep our own markets, and it can only be done by the labor and the capital going into partnership to do it. Only those who have been in the fight and know what a struggle it is can understand what such a system would mean. The employers, I think, might hesitate to take the men they have been fighting so long into counsel with them

as to the cost of work. I do not believe such confidence would be misplaced, and it is the only way to bridge the gulf that lies between them, and without such bridge there is no crossing, and no hope for the future of our industries here. I should not expect any opposition from the trades unions to such a plan. They must realize that unless a change takes place there will be a continued and increasing depression in the engineering trades here until everything we require in the way of machines will be imported from other parts of the country. There is no reason why we should not be able to hold our own on the Pacific coast in all the engineering trades, but in order to do so the men who plan and direct and finance must join hands in a close partnership with the workman, one and all having the same purpose in view: our own work for our own shops. Such a combination will make it possible for the other party, the man who orders the work, to have his motto also: My work goes to the shop at home.

[NOTE. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by March 15, 1910, for publication in a subsequent number of the JOURNAL.]

DISCUSSION OF PAPER BY WILLIAM H. BRYAN, "GOING VALUE AS AN ELEMENT IN THE APPRAISAL OF PUBLIC UTILITY PROPERTIES."

(Volume XLIII, Page 147, October, 1909.)

Mr. S. Bent Russell. — The author shows that "going value" has been officially recognized in appraisals both in case of those for purpose of sale and those for fixing rate. From the tenor of the paper it is pretty clear that the author has no bias against the allowance of "going value." He has, nevertheless, failed to present any good argument in favor of using "going value" as a basis of rates. His quotation from the Wisconsin decision on page 149 is by no means convincing in itself. Moreover, when we view it in the light of the author's subsequent discussion in regard to cost of producing income, we find its argument has no leg left to stand upon.

To make the point clearer, the Wisconsin authorities will allow "the actual reasonably wise expenditure of money towards getting the business of the plant established" (p. 149). If that were all, the ruling would almost stand unchallenged, but in the same paragraph we find the bars let down so that it seems a case of making the "going value" stand in inverse ratio to the income. Moreover, and on the other hand, we find that the author on the same page (149) states that it is not a question of what has actually been expended.

Again, in a subsequent statement (fourth paragraph, p. 153) the author indicates the futility of trying to find "the increased worth of the present system" from the income for rate revision. And this seems to be the author's view where rate revision is the object, even if a hypothetical fair income be substituted for the actual income.

In short, it appears that the author would make an appraisal rest on present value based on cost of reproducing, and can show no clear way of computing the cost of reproducing income that would be admissible as a basis for rate making. To put it another way: he apparently finds that the cost of reproducing an established business cannot consistently be coupled with the cost of reproducing the physical property in determining rates.

We may fairly conclude that the author has been able to find no logical justification for the use of "going value" as a basis of rates. May we not further conclude that the only sensible basis for rates is the physical or tangible value of the property?

As the "fair return" is an allowance that, within the limits set by custom, must be arbitrarily assumed, why apply it on a present value also arbitrarily assumed as it seems "going value" must largely be? May not the "fair return" be made great enough to recompense the parties concerned for all effort in obtaining business after the plant is ready to operate?

Reply of the Author to the Discussion of Mr. Russell. — The author has certainly no bias against the admission of "going value" in appraisals. The necessary cost of building up any business is as much a legitimate part of the investment as is the plant itself, and the earnings should carry and in time repay this, the same as other items of cost. The author accepts the definition of "going value" as the present cost of duplicating the present business. But he confesses to grave uncertainty as to the best method of estimating this cost. No suggestion yet made is free from objection, although the tentative or "cut and try" plan on page 151 seems best. The author welcomes Mr. Russell's concurrence in the plan pointed out near the bottom of page 151, that rates be fixed so that the resulting "fair return" would cover the cost of getting the business, i. e., the "going value." This is exactly what intelligent rate fixing should try to do.

Mr. E. W. Bemis. I have read with much interest Mr. Wm. H. Bryan's paper. I like the provision of his contract given on page 158, which he drew for a water works at Mexico, Mo., which provided that the city might purchase after fifteen years at "the then cost of duplication less depreciation of said property with 10 per cent. additional thereto as compensation for earning power, franchise value, going value, contingencies and all other tangible values of every nature whatsoever."

In order, however, to make the meaning still clearer, I would suggest that he add promoters' profits, development expenses, interest during construction, cost of financing, legal expenses, insurance, engineering administration, supervision and all other matters not appearing in an inventory of property in use. The above I would insert after his word "contingencies" in his Mexico contract. It is evidently his thought, but one cannot err by being as specific and all-embracing as possible.

I hold further that the principles to be adopted in appraising a plant which has not such a provision, but whose franchise has expired, is not the cost of duplication with all these elements in it, but the value that one can see in an inventory plus perhaps 10 per·cent. or 15 per cent. If the franchise has expired and if the plant has been fairly profitable, it should have amortized all the other expenses, and probably has done so out of earnings in the previous years.

OBITUARY.

Edwin William Ellis.

Member of the Boston Society of Civil Engineers.

Edwin William Ellis, son of George and Esther (Muir) Ellis, was born in Middleboro, Mass., February 13, 1874. He was educated in the public schools of Pawtucket, R. I., graduating from the grammar school in 1889 and continuing his studies in mechanical drawing, in the evening schools, from 1890 to 1894.

In 1889 he entered the office of J. A. Latham, of Providence, R. I., serving an apprenticeship of three years, and continuing with him until 1894. He then worked as transitman with J. E. Judson, at Pawtucket, R. I., until October 3, 1894. He was employed for different periods by Arthur J. Patten, at Waterbury, Conn., and by the Benjamin F. Smith Company, at Pawtucket, R. I.

He entered the city engineer's office at Pawtucket, R. I., May 9, 1898, and was employed there until December 28, 1901, as assistant and draftsman. Coming to Boston in 1902, he entered the employ of E. W. Everson & Co., contractors, as civil engineer on tunnels, sewer, heavy foundation work, brick and stone masonry, and road building. During the summers of 1905 and 1906 he was employed by the Water Board of the city of Cambridge as inspector and foreman on the construction of a large concrete conduit. From October 21, 1905, to January 26, 1906, and from December 22, 1906, to November 30, 1907, he was employed as inspector of masonry in the Engineering Department of the city of Cambridge, on bridge foundation work. From April 9, 1908, to October 27, 1908, and from May 10, 1909, until his death, he was in the employ of the Charles River Basin Commission, first as inspector of pile driving and masonry and later on the finishing of the Boston embankment.

Mr. Ellis became a member of the Boston Society of Civil Engineers on January 24, 1906. He died of appendicitis August 3, 1909, at the Boston Homœopathic Hospital. He leaves a brother and cousin as his only near relatives.

In his work he was thoroughly honest, conscientious and loyal to his employer, whether contractor or corporation, and had unusual skill and tact as an inspector in securing results without unnecessary friction or contention. In handling men on construction work, his skill and judgment were unusually good.

Of a simple, modest and retiring disposition, Mr. Ellis was not well known by a large number of the members of this Society. To those who became acquainted with him, however, these qualities appealed very strongly. Those who knew him best, liked him most. He seemed to have the quality of tact, which is all too rare among engineers, of securing and retaining the respect and esteem of all with whom he came in contact.

L. M. Hastings,
John N. Ferguson,
Committee.

Association of Engineering Societies.

Vol. XLIII. JULY, 1909. No. 1.

PROCEEDINGS.

Technical Society of the Pacific Coast.

San Francisco, July 16, 1909. — A regular meeting of the Society was held on July 16, 1909, at the Hotel Argonaut, where dinner was had before the business of the meeting was taken up.

President George W. Dickie presided.

The minutes of the last regular meeting were read and approved.

The Secretary stated that owing to his recent illness certain matters had been postponed and necessarily delayed, but that now the regular business of the Society would take the usual course, from month to month, without any interruption.

The following candidates, who have applied for membership at the last regular meeting, were duly elected by a vote of the members present:

Mr. Bruce Lloyd, vice-president of the Ker-Lloyd Iron Works, San Francisco; Mr. Charles E. Ker, president of the Ker-Lloyd Iron Works, San Francisco; Mr. O. Jacobsen, mechanical engineer, San Francisco.

Mr. B. J. S. Cahill addressed the Society on an important municipal subject entitled, " A Civic Center for San Francisco."

This paper was discussed by the members present, and ordered to be submitted to the Secretary to be prepared for publication in the Journal of the Association of Engineering Societies.

The meeting thereupon adjourned.

Attest,

Otto von Geldern, *Secretary.*

ASSOCIATION

OF

ENGINEERING SOCIETIES.

VOL. XLIII. AUGUST, 1909. No. 2.

PROCEEDINGS.

Louisiana Engineering Society.

Synopsis of Work Done, January–June, 1909.

AT the annual meeting on January 9, reports of all officers and committees were read, and officers for 1909 were elected. Mr. C. W. Wood delivered the address as retiring president.

The meeting adjourned to the banquet, arranged by chairman J. F. Coleman, at Galatoire's, and a most enjoyable evening was spent by the members.

The Board of Direction, at their meeting of January 16, created an Advertising Committee to solicit advertisements to the Journal. The committee, under the able chairmanship of Mr. Paul L. Brand, did some successful work.

The Society, at its meeting on February 8, authorized the Library Committee to properly catalogue and index the library. This committee, with Mr. J. W. Armstrong as chairman, has accomplished excellent results. A competent cataloguer was employed to do the work, and we now have our entire library, as well as the engineering literature contained in the three large libraries of the city, namely, the Howard, New Orleans Public and Tulane University, card indexed, and the books of our library shelved, all according to the Standard Dewey System of Cataloguing. This gives our members a ready reference to all engineering works contained in those four libraries, and provision will be made to keep this system up to date.

The Future New Orleans Committee was reorganized. This committee has employed a draftsman, who is now engaged in making a map of future New Orleans, as designed by the committee, for 1 000 000 inhabitants.

On March 8, Prof. W. B. Gregory, member Louisiana Engineering Society, read a paper on the " Test of a Gas Compressor."

On April 12, J. W. Armstrong, member Louisiana Engineering Society, gave a description of the intakes of the new water works systems for both New Orleans and Algiers.

On May 10, the Society created an honorary roll of membership, by an amendment to the Constitution. Prof. John M. Ordway was elected an honorary member at this meeting.

Mr. Lyman C. Reed, member Louisiana Engineering Society, read a paper entitled "Heat, Its Use and Distribution."

On June 14, the Society postponed the outing until fall.

The McKinley Congressional Bill, providing for the establishment of engineering experiment stations at land grant colleges, was endorsed.

Mr. Alfred F. Theard, member Louisiana Engineering Society, read a paper on "Chalmette Monument, Its Recent Enlargement."

The Society decided to adjourn for the months of July and August.

L. C. Datz, *Secretary.*

Association of Engineering Societies.

Vol. XLIII. **SEPTEMBER, 1909.** No. 3.

PROCEEDINGS.

Montana Society of Engineers.

Butte, Mont., May 8, 1909. — The May meeting of the Society was held on the above date, with a quorum present, and President C. H. Bowman presided. The minutes of the last meeting were read and approved. The application of Wm. J. McMahon for membership in the Society was read, approved and the regular ballot ordered. Messrs. Inch and Morris were elected members by a unanimous vote. Prof. F. W. Traphagen and Mr. Kilgore, of the Colorado School of Mines, were present and the chair appointed Messrs. Moore and Hobart as a committee to confer with Professor Traphagen about entertaining the Colorado students visiting Butte.

The chair appointed a program committee for the balance of the year. Said committee consists of Messrs. Moore, Pope and Hobart. Mr. H. H. Cochrane gave a very entertaining and instructive talk on the various kinds of electric lamps in common use, after which the Society adjourned till the September meeting.

Clinton H. Moore, *Secretary.*

Butte, Mont., September 11, 1909. — The regular meeting of the Society was held on the above-named date in accord with the action taken at the May meeting. President C. H. Bowman presided. The minutes of the May meeting were approved as read. Wm. J. McMahon was elected to active membership in the Society. The Committee on Program recommended that Mr. James H. Ellison be invited to furnish a talk or paper on " The Taft Tunnel Project," and the Secretary was instructed to extend the invitation to Mr. Ellison. The resignation of F. A. Schiertz was presented and accepted. The chair named the following committee on nomination of officers for next year: Messrs. Carroll, Dunshee and Evensen.

Adjourned.

Clinton H. Moore, *Secretary.*

Louisiana Engineering Society.

MEMORIAL RESOLUTIONS.

(Adopted September 13, 1909.)

On the Death of Prof. J. M. Ordway.

Whereas, our esteemed friend and the only honorary member of our Society, John Morse Ordway, has been removed from our midst by death; be it

Resolved, that the members of the Louisiana Engineering Society, in regular meeting assembled, express their deep sorrow at the loss of Dr. Ordway, and further express their full recognition of his high character as a man and a scholar.

His long life was devoted to the advancement of the arts and sciences, and his attainments in the field of technical education and industrial chemistry were of the highest order.

His ten years as an active member of our Society showed a devotion to its interests and welfare that was always an inspiration to his fellow members.

Resolved, that these resolutions be spread upon the minutes of the Society, and a copy thereof be sent to the family of the deceased.

On the Death of Major H. B. Richardson.

The Louisiana Engineering Society records its deep sorrow at the death of its member, Major Henry B. Richardson, and its appreciation of his services to the state and of his qualities as a citizen, an engineer and a friend.

Major Richardson was one of the first to enlist in defense of the South during the Civil War, through which he served as an engineer with great distinction. His service was eminently valuable from a faculty for rapid, daring and accurate reconnaissance.

While possessing a breadth of knowledge and experience fitting him for the general practice of the profession, he chose for his life work the study of alluvial rivers, and particularly of the Mississippi and the reclamation of its alluvial valley from overflow.

The predominating interest of Louisiana in this work, his close and alert power of observation, his sound conclusions, his firmness of resolve and his long experience, covering the four decades during which the system grew from a frail barrier, breached by every flood of more than average height, to its present dimensions, all mark him as probably the principal contributor in this great work of reclamation.

The evidence of the value of his service and the absolute confidence which he had acquired is his retention of his high office, which was subject to change with every incoming administration, for twenty-four years, or until he resigned to enter the service of the general government as a member of the Mississippi River Commission. He was incapable of entering any selfish contention for personal promotion, and work and fame came to him only as the logical result of proved character and capacity.

We all here knew him as the modest, unselfish, wise, firm and courageous gentleman, the distinguished engineer, the true friend.

The Club begs to extend its warmest sympathy to his widow and the other surviving members of his family.

Utah Society of Engineers.

Salt Lake City, Utah, September 18. — The meeting was in the nature of a house-warming and smoker in order to formally open the Society's new headquarters in the Newhouse Building. An initial equipment of furniture has been furnished and the rooms supplied with back files of eighteen technical and engineering periodicals.

Under the head of reports of committees, Secretary McNicol, as chairman of the Program Committee, reported that arrangements had been made for the presentation of several timely and interesting papers during the coming season, completed list to be announced later when dates have been assigned.

The matter of entertaining the members of the mining engineers returning East from Seattle was discussed at some length and a committee was appointed with Mr. Ben. F. Tibby as chairman to devise ways and means of conducting the visitors through the various mining camps of the state while they are here. It is expected that there will be one hundred visiting mining engineers in the city from October 5 to 9.

Delegates were appointed to represent the Society at the Goldfield Mining Congress.

The following gentlemen were elected to membership in the Utah Society of Engineers: George M. Bacon, Anders Bagge Villadsen, Jens Martin Villadsen, Henry C. Hoyt, L. Douglas Anderson, Charles Ulrich Heuser.

Applications were presented from the following: Alexander Grant McGregor, Joseph Ulmer, Henry Denison Randall, Markham Cheever, all of which will be acted upon at the next regular meeting of the Society.

Attendance, 43.

A special meeting was called September 30 for the purpose of extending a formal reception to Mr. Ralph W. Pope, Secretary of the American Institute of Electrical Engineers. Addresses were made by President Jos. F. Merril, Leonard Wilson, John C. Jones, D. McNicol, A. G. McGregor, O. H. Skidmore, A. L. Woodhouse and City Engineer L. C. Kelsey. Mr. O. A. Honnold acted as chairman of the meeting.

In response to the speeches of welcome, Mr. Pope gave a very interesting account of the workings of the Institute, and of the objects of his mission. Mr. Pope was on his way back from Seattle where he attended the electrical festivities of the Alaska-Yukon-Pacific Exposition. Mr. Pope remained in Salt Lake City five days, during which time he was taken to the various hydro-electric plants throughout the state.

D. McNicol, *Secretary.*

Association of Engineering Societies.

Vol. XLIII. | OCTOBER, 1909. | No. 4.

PROCEEDINGS.

Engineers' Club of St. Louis.

St. Louis, May 19, 1909. — The 670th meeting of the Engineers' Club of St. Louis was held at the Club rooms, 3817 Olive Street, on Wednesday evening, May 19, 1909. President Wall presided. There were present twenty-three members and five visitors.

The minutes of the 669th meeting were read and approved. The minutes of the 464th meeting of the Executive Committee were read.

Mr. Roy A. Campbell was elected to membership. Applications for membership from Mr. Robert H. Brown and Mr. Ernest W. Pittman were read.

The Secretary read a letter from the Board of Freeholders asking that the Club name a representative or representatives to appear before it for the purpose of making specific recommendations. After some discussion, it was moved, seconded and carried that the Chair appoint special representatives, in response to the request of the Board of Freeholders, and that these representatives be requested to make such recommendations as may be indorsed by the Club, definite instructions to be given the representatives later. The Chair appointed Messrs. M. L. Holman and Robert Moore.

The Secretary read a letter from the Central Trades and Labor Union in which was set forth a series of resolutions drawn up by that body for the consideration of the Board of Freeholders, and requesting the Engineers' Club to endorse them. The matter was laid on the table.

Mr. W. H. Bryan, on behalf of the committee appointed at the last meeting to take up with the authorities at Jefferson City the bill for the regulation of the practice of architecture and the licensing of architects, reported that the bill had been killed and asked that the committee be discharged. There being no objection, the committee was declared discharged.

Mr. H. W. Whitten then presented the paper of the evening, on "The Effect of Air Leakage on Heating and Ventilation." The paper described the results of a series of tests on the amount of air leakage through window

frames of the ordinary type and also when provided with a special weather stripping; also the rate of heating and cooling of the air in a specially constructed compartment, provided with a window and arranged to be exposed to winds of varying velocity and direction.

The discussion following the paper was participated in by Messrs. Bryan, Whitten, Kauffman and Langsdorf.

On motion, duly seconded, it was unanimously voted to extend the thanks of the Club to Mr. Whitten for his courtesy in preparing the paper.

Adjourned.

A. S. LANGSDORF, *Secretary.*

ST. LOUIS, JUNE 2, 1909. — The 671st meeting of the Engineers' Club of St. Louis was held at the Club rooms, 3817 Olive Street, on Wednesday evening, June 2, 1909, at 8.30 o'clock. President Wall presided. There were present twenty-five members and twenty-two visitors.

On motion duly seconded and carried it was voted that the Secretary cast the ballot of the meeting for the election of the following gentlemen whose applications had been duly approved by the Executive Committee: Robert H. Brown, Ernest W. Pittman. The Secretary reporting that this had been done, the two gentlemen named were declared elected to membership in the Club.

Col. J. A. Ockerson then presented a very interesting address, fully illustrated with lantern slides, on " Scenes in Russia and Other European Countries, and Scenes by the Way."

After the conclusion of the address the members and their guests, among whom was a large number of ladies, adjourned to the adjoining rooms where the Entertainment Committee had provided refreshments.

Adjourned.

A. S. LANGSDORF, *Secretary.*

ST. LOUIS, SEPTEMBER 15, 1909. — The 672d meeting of the Engineers' Club of St. Louis was held at the Club rooms, 3817 Olive Street, on Wednesday, September 15, 1909, President Wall presiding. There were present twenty members and six visitors. In the absence of the regular Secretary the minutes of the preceding Club meetings and Executive Committee meetings were not read.

Mr. Wm. H. Bryan presented a memorial to Mr. William C. Eimbeck, a charter member of the Club, who died March 27, 1909.

The application of Mr. S. C. Baker for membership was read. President Wall presented to the meeting a proposition from the American Society of Mechanical Engineers to join with the Engineers' Club of St. Louis in holding joint monthly meetings. On motion duly made and seconded it was voted that the Executive Committee be given power to act in making arrangements with the American Society of Mechanical Engineers for such joint meetings.

Mr. J. B. Emerson then presented the paper of the evening, on " The Possibilities of Service from a Bureau of Inspection and Tests." The subsequent discussion was participated in by Messrs. E. Posselt, M. Schuyler, and John N. Ostrom.

Adjourned.

A. S. LANGSDORF, *Secretary.*

Boston Society of Civil Engineers.

Boston, September 15, 1909. — A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 8 o'clock P.M., President George B. Francis in the chair; eighty-eight members and visitors present.

The record of the last meeting was read and approved.

The President announced the death of Edwin W. Ellis, a member of the Society, which occurred on August 3, 1909, and appointed the following members a committee to prepare a memoir: Messrs. Lewis M. Hastings and John N. Ferguson.

Mr. Holmes, for the committee to prepare a memoir of Charles D. Elliot, read its report.

On motion of Mr. Fay, the Secretary was directed to tender the thanks of the Society to those who had placed automobiles at the service of the committee appointed to entertain members of the American Society of Civil Engineers attending the Convention at Bretton Woods who might come to Boston. Cars were furnished by the Metropolitan Water Board, Mr. Charles S. Sergeant, Vice-President of the Boston Elevated Railway Company, Mr. Harry P. Nawn and by the following members of the Society: William L. Miller, Frederic P. Stearns, Frank A. Barbour and George A. Kimball.

The thanks of the Society were also voted to the officials of the Boston & Albany Railroad Company for courtesies extended this Society on the occasion of the visit of the members to the East Boston Terminal Improvements.

The paper of the evening was by Mr. James W. Rollins, Jr., and was entitled, "Building the Shut-off Dam at the Charles River Basin."

The discussion following the reading of the paper was participated in by Messrs. Harold P. Farrington, Frederic H. Fay and President George B. Francis. The paper and discussions were illustrated by lantern slides.

Adjourned.

S. E. Tinkham, *Secretary.*

Boston, October 6, 1909. — A regular meeting of the Sanitary Section was held at the Boston City Club.

The meeting was called to order at 7.30 P.M. by Chairman F. A. Barbour. Mr. Alexis H. French read a paper descriptive of the Brookline Comfort Station. Following Mr. French, Mr. Arthur D. Marble read a description of the Comfort Station at Lawrence. Both of these stations were novel in design, and the papers were illustrated with large scale drawings and photographs. Many details of design of such structures were described and methods and cost of operation were discussed.

Mr. Harvey, of the J. L. Mott Iron Works, discussed a few of the debatable points in connection with the plumbing fixtures for public purposes. Regarding the type of urinal, he stated that he preferred the long porcelain wall type to the individual bowl type on account of the better washing of the surface around and below the point of approach. He preferred glazed surfaces to marble partitions. Regarding closets, he said that the matter of flushing the water and the finish of the seat were matters of debate. The integral seat, he said, was not a success. When

placed in institutions they were frequently covered with all sorts of wooden or textile seats. The seat having part of its circumference wooden and part porcelain is the latest device and is an effective compromise between the integral seat and the all-wooden seat. Mr. Harvey stated that a cleanly appearance is of the most importance in design of public comfort stations, where not only must the premises be kept clean, but must be so built that the presence of any dirt will be so noticeable that its immediate removal will be obligatory. In his opinion all general apparatus for flushing should be in a separate room. He approved of automatic seat flush tanks and believed that flush valves in connection with closets were fully as reliable as the ordinary flush tank and chain. Mr. Harvey said that the flush tanks appealed to him in cases where the closets were flushed frequently. In many places the period between usings does not permit the flush tank to completely fill.

Mr. Bunting described several types of fixtures which in his experience had proved to be most satisfactory. He did not like the siphon urinal of the Terminal Station type on account of the large volume of water contained in it permanently, nor the wall type on account of the liability of portions of the surface thereon becoming foul because of inadequate distribution of water.

Mr. Humphrey described " Kleen Spra " videt.

Messrs. Joseph Enright Conley and Joseph B. Stewart, Jr., were elected members of the Section.

About twenty-seven members and guests were present. In the afternoon the Section enjoyed an excursion to Brookline, where the comfort station, the new transfer station, the new water-works reservoir and also some deep sewer construction were inspected under the guidance of Mr. Alexis H. French, Town Engineer.

Robert Spurr Weston, *Clerk.*

Civil Engineers' Society of St. Paul.

St. Paul, Minn., October 11, 1909. — The monthly meeting of the Civil Engineers' Society of St. Paul was held in the Society's club room in the Old State Capitol Building, on Monday evening, October 11, 1909, with President H. J. Bernier in the chair. There were present nine members and seven visitors.

The reading of the minutes of the previous meeting was dispensed with.

The feature of the evening was to be a lecture on " Terminal Freight Handling," by Mr. H. McL. Harding, but, owing to his illness and inability to be there, a general discussion of the subject was participated in among those present, printed advance copies having been sent the members. This discussion was supplemented by a descriptive talk on the Spence portable electric conveyors, by Mr. W. W. Spence, of St. Paul.

It was then moved and carried that action on the applications of Messrs. A. J. Rasmussen and Paul K. Pulte, for full membership, Mr. F. Wm. Fiske, Jr., for junior membership, and the promotion of present Junior Member Mr. J. B. Mitchell to full membership be deferred at this time.

The meeting thereupon adjourned.

D. F. Jurgensen, *Secretary.*

Engineers' Society of Milwaukee.

TREASURER'S REPORT FOR YEAR ENDING OCTOBER 20, 1909.

RECEIPTS.

From E. P. Worden, ex-treasurer	$537.77
From fees and dues collected	897.00
Received on Gary account	441.50
	$1 876.27

EXPENDITURES.

Seven months' rent, Builders Club	$105.00	
Three quarterly assessments, JOURNAL	169.00	
Printing and postage	121.50	
Paid on Gary account — excursion	525.00	
Refreshments	17.90	
Power Improvement Company, slides	50.00	
Furniture	40.90	
Stenographer	5.00	
City Charter	5.00	
Lantern rental	24.00	
A. R. Schmidt	4.70	
Cash and name books	2.50	
Excess dues — refund	7.00	
Excess bank deposit	5.00	
Letter file	.75	
One rubber stamp	.25	
Expressage	.25	
		$1 083.75
Cash on hand		792.52
		$1 876.27

(Signed) M. A. BECK, *Treasurer*.

Association of Engineering Societies.

Vol. XLIII. **NOVEMBER, 1909.** No. 5.

PROCEEDINGS.

Engineers' Club of St. Louis.

St. Louis, October 20, 1909. — The 674th meeting of the Engineers' Club of St. Louis was held at the Club Rooms, 3817 Olive Street, on Wednesday evening, October 20, 1909, at 8.30 o'clock, President Wall in the chair. There were present fourteen members and six visitors.

The minutes of the 673d meeting were read and approved. The minutes of the 468th meeting of the Executive Committee were read.

The following were elected: S. C. Baker (member), M. W. Cluxton (member), C. M. Daily (member), Thomas N. Jacob (member), E. H. Lawrence (member), J. D. Macpherson (member), Richard Gildehaus, Jr. (junior member).

The Secretary read an application for membership from Mr. Philip Aylett, which was referred to the Executive Committee for approval. The Secretary read a letter from the president of the Academy of Science calling attention to reports of disorderly conduct in the vicinity of the Academy building and asking the members of the Engineers' Club to report any such conduct that might come under their observation.

It was moved by Mr. Langsdorf and seconded by Mr. Bryan that the Executive Committee be authorized to make arrangements for joint meetings between the Engineers' Club of St. Louis and the St. Louis Section of the American Institute of Electrical Engineers. Motion carried.

Mr. William H. Bryan then presented a very interesting and instructive paper on "Going Value as an Element in the Appraisal of Public Utility Properties." The paper pointed out the methods used by the Wisconsin Commission in determining the magnitude of the going value as compared with the different method advocated by Mr. Alvord in a recent paper, and indicated certain simplifications that seem to be necessary in individual cases.

The lively discussion following the reading of the paper was participated in by Messrs. Bryan, Toensfeldt, Schuyler, Wall, Hendrich, Layman, Childs and Roux.

Adjourned.

A. S. Langsdorf, *Secretary.*

Technical Society of the Pacific Coast.

THE regular meeting of the Technical Society of the Pacific Coast was held on Friday, September 24, at the residence of the Secretary, 1926 Broadway.

The minutes of the last regular meeting were read and approved.

The Secretary read a paper on the subject of "The Future Water Supply for San Francisco," in which he pointed out many of the impracticable features of the project to obtain water from the Hetch-Hetchy Valley. In the course of his paper the quantities at disposal held in the reservoirs were touched upon, and great stress was laid upon the fact that under the permit obtained from the Interior Department it was necessary to bring the Lake Eleanor Reservoir to its fullest possible capacity before the Hetch-Hetchy Valley could by any possibility be considered, which makes the real problem one of a distant future. It was pointed out that the more practicable solution of the problem lay in developing the water resources in the more immediate vicinity of San Francisco, which upon proper development will yield over 100 000 000 gal. a day.

A short discussion of the paper followed.

The President appointed a committee to make arrangements to visit the present water supply of the city for the purpose of inspecting the available resources at the present time.

The committee consists of Mr. Uhlig, Mr. Homberger, Mr. A. T. Herrmann, Mr. Modina and Mr. Tower, to which were added the Secretary and the President as *ex-officio* members.

The meeting thereupon adjourned, after which the members spent a social evening as the guests of the Secretary.

OTTO VON GELDERN, *Secretary.*

SAN FRANCISCO, NOVEMBER 26, 1909. — Regular meeting of the Technical Society of the Pacific Coast held at the Hotel Argonaut, where dinner was had before the regular business of the evening was taken up.

President Dickie called the meeting to order at eight o'clock, and the Secretary read the minutes of the last regular meeting, which were approved upon motion. The following Nominating Committee was appointed to prepare a ticket of officers for the ensuing year:

Morton L. Tower, chairman; Charles E. Beugler, H. A. Brigham, Frank P. Medina and Adolf Lietz.

The President, Mr. George W. Dickie, thereupon addressed the members on the subject of "The Engineering Trades on the Pacific Coast," in which he called attention to the unsatisfactory condition in which the item of labor enters into engineering or industrial estimates at the present time, asserting emphatically that the difficulty will not be overcome until some more rational method is found which will make this factor or element a more constant one.

The remedy proposed lies in an entire change of attitude towards each other of the employer and the employed. They should become associates in the labor part of every estimate. A coöperation of these two parties, in which the representatives of labor will make their own estimate of cost, abiding by their estimate, and sharing in the ultimate profits to the extent

agreed upon between the two parties, is, in Mr. Dickie's opinion, the only rational solution of this intricate and vexed question,

The paper read by the President was discussed with great interest by Mr. Hermann Schussler, Mr. Bruce Lloyd, Mr. Harry Larkin and others.

Mr. Hermann Schussler, as guest of the Society, related some incidents of great interest to the members, after which it was arranged that this Society hold a meeting for the purpose of affording its members an opportunity to attend a lecture on the subject of the " Water Supply of San Francisco."

Mr. Schussler stated that it would give him pleasure to take eight or nine members of the Society over the works of the Spring Valley Water Company, in order to show them the actual condition and the magnitude of these works and to acquaint them with the real status of the plant which furnishes water to the city of San Francisco.

The offer to make this visit was gratefully accepted. The President instructed the Secretary to make the necessary arrangements for the lecture and the proposed trip.

The meeting thereupon adjourned.

OTTO VON GELDERN, *Secretary.*

Association of Engineering Societies.

Vol. XLIII. **DECEMBER, 1909.** No. 6.

PROCEEDINGS.

Boston Society of Civil Engineers.

Boston, October 20, 1909. — A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 7.40 o'clock P.M., Vice-President Charles T. Main in the chair; one hundred and eighty members and visitors present, including members of the Boston Section of the American Society of Mechanical Engineers.

The record of the last meeting was read and approved.

Messrs. Theodore M. Beach, William H. Ellis, Jr., William F. Farley, Oren L. Goodridge, Edward R. Hyde, Daniel P. Kelley, John L. Mann, Stanley A. Miller, Charles W. Robinson, Conant W. Ruth, Harry F. Sawtelle and Charles E. F. Stetson were elected members of the Society.

The chair stated that he had the report of Mr. Frank S. Hart, the committee appointed to prepare a memoir of Mr. Arthur W. Hunking. As Mr. Hart was not present, on motion of Mr. Bryant it was voted that the memoir of Mr. Hunking be accepted, that its reading be dispensed with, and the Committee of Publications of the Board of Government be authorized to print same in the Journal.

The chair announced the death of William Parker, a member of the Society, which occurred on September 30, 1909. On motion of Mr. Bryant, it was voted that the president appoint a committee to prepare a memoir of our late fellow-member, William Parker, the same to be presented to the Society by title, for publication in the Journal. The president has appointed as this committee: Messrs. Walter Shepard, Herbert C. Keith and Edward A. Haskell.

In taking up the literary exercises of the evening, the chairman, Mr. Charles T. Main, said in part that it was expected that Professor Hollis, who is chairman of the Boston branch of the American Society of Mechanical Engineers, would be here to preside at the literary exercises during the latter part of the evening, when the meeting will really be in part a meeting of the Society of Mechanical Engineers.

A few months ago the Boston Society of Civil Engineers appointed a committee to consider the advisability of establishing a mechanical

section of the Boston Society. About the same time the American Society of Mechanical Engineers were discussing the advisability of starting a Boston branch of that society.

All of the members of the committee appointed by the Boston Society were members of the American Society of Mechanical Engineers, and, naturally, the question of the advisability of starting a Boston branch of the American Society of Mechanical Engineers was turned over to that committee.

But the question arose as to which would be the greater benefit to the greater number of engineers, — a mechanical section of the Boston Society, or a Boston branch of the American Society.

It appeared that the number of mechanical engineers who were members of the Boston Society of Civil Engineers was relatively small as compared with the number of mechanical engineers in the city of Boston and with the number of mechanical engineers who were members of the American Society.

In view of this, it seemed to the committee that a Boston branch of the American Society would be of greater benefit to the engineers in general than a mechanical section of the Boston Society. The committee, however, has refrained from making a final report to the Boston Society, because they do not want to have too many societies, and think it advisable that there should be a concert of methods, and that all effort should be concentrated, if possible, in one general society.

The reason for this joint meeting of the Boston Society of Civil Engineers and the American Society of Mechanical Engineers is that we might see if there be some possible way in which these two bodies can work together.

Prof. Gaetano Lanza then read the paper of the evening, which had been prepared by himself and Mr. Lawrence S. Smith, entitled, "Comparison of the Results Obtained by the Use of Three Theories of the Distribution of the Stresses in Reinforced Concrete Beams with the Experimental Results."

A general discussion followed the reading of the paper, which was participated in by Messrs. Sanford E. Thompson, Desmond FitzGerald, Robert L. Read, C. M. Spofford, H. F. Bryant, G. F. Swain and R. R. Newman, of the Boston Society, and Fred. Sumner Hinds, of the American Society of Mechanical Engineers. The Secretary also read a discussion prepared by Mr. J. R. Worcester, past President of the Boston Society of Civil Engineers.

Adjourned.

S. E. Tinkham, *Secretary.*

Boston, November 17, 1909.— A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 7.45 o'clock P.M., President George B. Francis in the chair. Eighty-one members and visitors present.

The record of the last meeting was read and approved.

Messrs. Walter C. Durfee, Charles H. Dutton, Herbert T. Gerrish Philip H. Ladd, Bernard S. Rose, William T. Shaw, George R. Wadsworth and John H. Wiseman were elected members of the Society.

The Secretary presented the report of the committee appointed to prepare a memoir of our late associate, Edwin W. Ellis, and on motion it was voted to accept the report and order it to be printed in the JOURNAL.

The first paper of the evening, entitled "Waterproofing of Engineering Structures," by Joseph H. O'Brien, was read by its author, and was very fully illustrated by lantern slides. A discussion followed by the President and Messrs. Skinner, Hodgdon and Larned, of the Society, and by Mr. Edward W. DeKnight, of New York.

The second paper was by Gilbert S. Vickery, entitled "The Use of Manard Steel in Railroad Track." The paper was also illustrated by lantern slides. A general discussion followed the reading of the paper, and at its conclusion the Society adjourned.

S. E. TINKHAM, *Secretary.*

The December meeting of the Sanitary Section was held at the Boston City Club on Wednesday evening, December 1.

Mr. Ralph J. Sherriff was elected a member of the Section.

Prof. Earle B. Phelps read a paper on disinfection of sewage by means of chemicals, especially calcium hypochlorite, and Mr. George A. Johnson read a companion paper on the disinfection of water by similar means. The paper was discussed by Messrs. Kinnicutt, Winslow, Gage, Clark, Pratt and others. Sixty-nine members and guests were present.

ROBERT SPURR WESTON, *Clerk.*

Civil Engineers' Society of St. Paul.

ST. PAUL, MINN., NOVEMBER 8, 1909. — The monthly meeting of the Civil Engineers' Society of St. Paul was held in the Society's club room, in the Old State Capitol Building, on Monday evening, November 8, 1909, with President H. J. Bernier in the chair.

There were present eight members. The minutes of the previous meeting were read and approved.

The Secretary was directed to advise Mr. Martin T. Roche, president of the Northwestern Cement Products Association, that the members individually of our Society would be glad to attend the sixth annual convention of the association, which is to be held at St. Paul in March next; and that further consideration would be given his suggestion as to this Society holding any meeting during the said convention.

The Secretary was directed to advise Mr. C. A. P. Turner (member Am. Soc. C. E.) that the Society would be glad to be the recipient of a copy of one of his new books on reinforced concrete; same to be placed upon the shelves of its library.

The Secretary was authorized to arrange for the purchase of three additional units, for the elastic bookcases, also for the purchase of a copy of Vols. 29 and 30 of the Transactions of the American Society of Mechanical Engineers; and also a copy of "Principles of Reinforced Concrete Construction," by Turneaure and Maurer.

The applications of Messrs. A. J. Rasmussen for full membership, F. W. Fiske, Jr., and Jno. E. Fearing for junior membership, were

read; it was then moved, seconded and carried that the Secretary cast the ballot of the Society, electing these applicants as petitioned.

The meeting thereupon adjourned.

D. F. Jurgensen, *Secretary.*

St. Paul, Minn., December 13, 1909. — The regular monthly meeting of the Civil Engineers' Society of St. Paul was held in the Society's room in the Old State Capitol Building on Monday evening, December 13, 1909, with President H. J. Bernier in the chair. There were present eight members and one junior member.

The minutes of the previous meeting were read and approved.

It was moved, seconded and carried that the Hon. A. O. Eberhart, present governor of the state of Minnesota, be elected honorary member of the Society, the intent being that he take the place in the Society of his lamented predecessor, the Hon. John A. Johnson.

It was moved, seconded and carried that the Secretary write Mr. P. K. Pulte, requesting him to submit an amended application for full membership in the Society; it to contain his occupations up to date. This for the purpose of the further consideration of his petition for membership by the Society.

It was moved, seconded and carried that the Secretary notify all members that the question of amending Article XVII of the Constitution, to read: "The regular annual dues for resident membership shall be: for members, $5 per year; for non-resident, $2 per year; same to be effective January 1, 1910," would be taken up by the Society at its next regular meeting, which will be held on the evening of January 10, 1910, which meeting will be the regular annual meeting.

Moved, seconded and carried that the Society would hold its customary annual banquet on the evening of January 10, 1910, which is the annual meeting, same to be held in the rooms of the Commercial Club of St. Paul, and to follow the election of officers, business meeting to be called to order at 6.30 P.M. in the secretary's room of the said Commercial Club. Banquet to follow at 7.30 P.M. Messrs. Wolff and Armstrong were appointed a committee to arrange for the banquet and use of the secretary's room for the business meeting; Messrs. Palmer and Mitchell were appointed a committee to arrange for music.

The Secretary was directed to advise certain delinquent members of the amounts they were indebted to the Society and to urge immediate payment of such accounts.

The Secretary was directed to invite the president and secretary of the Minneapolis Engineers' Club, Mr. Andrew Rinker, city engineer of Minneapolis. Mr. George W. Cooley, secretary and engineer for the Minnesota State Highway Commission, and Mr. L. W. Rundlett, Commissioner of Public Works, St. Paul, to attend our banquet.

The Secretary was directed to acknowledge receipt of copy of "Concrete Steel Construction by Turner," and to express to Mr. C. A. P. Turner the thanks of the Society for his generous donation.

The meeting thereupon adjourned.

D. F. Jurgensen, *Secretary.*

Montana Society of Engineers.

BUTTE, MONT., November 13, 1909. — The monthly meeting of the society for November was called to order at the appointed hour, Mr. J. H. Harper presiding. Minutes of prior meeting approved.

The Committee on Nomination of Officers for the ensuing year recommended the following list:

President — Frank M. Smith.

First Vice-President — F. W. C. Whyte.

Second Vice-President — Robert A. McArthur.

Secretary and Librarian — Clinton H. Moore.

Treasurer and Member of the Board of Managers of the Association of Engineering Societies — Samuel Barker, Jr.

Trustee for Three Years — John D. Pope.

The report was adopted and the Secretary instructed to send out ballots.

The resignation of Harry C. Wilmot was presented and accepted.

The Secretary reported the transfer of the following members to the Corresponding Member Class: Messrs. Wynne, Wright, Tannatt and C. H. Repath to membership in the Utah Society of Engineers.

On motion, Butte was selected as the place for holding the next annual meeting, January 6, 7, 8, 1910, and the chair named the following Committee of Arrangements: John C. Adams, Robert A. McArthur, John D. Pope.

Mr. J. H. Ellison, one of the charter members of the society, gave a very interesting account of the building of the St. Paul Pass Tunnel, in western Montana, on the line of the Milwaukee, St. Paul & Puget Sound Railway, and the members showed their appreciation of the information given by a unanimous vote of thanks.

Adjourned.

CLINTON H. MOORE, *Secretary.*

BUTTE, MONT., DECEMBER 11, 1909. — The December meeting of the Society was called to order by President C. H. Bowman, with a quorum present. The minutes of the last meeting were read and approved. The Secretary presented the application of Mr. Charles H. Hills for membership in the Society, and the same being approved, the usual ballot was ordered. The Committee of Arrangements for the annual meeting gave a verbal report and was given further time to complete their labors.

Adjournment.

CLINTON H. MOORE, *Secretary.*